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Works Administration

John Richards

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WORKS ADMINISTRATION.

Lectures before the Students of the Leland Stanford Junior University, Palo Alto, California.

BY J. RICHARDS.

No. 1. October 17th, 1895.

When Professor Smith first mentioned the subject of lectures on "Works Administration," or to use a more familiar term, shop management, the impression was that such a theme could not be treated so as to have interest separately from the regular studies you are pursuing here, but on more reflection it occurred to me, as it had undoubtedly done to Professor Smith, that while it was a part and parcel of technical education it was in the main separate and unteachable by the usual methods, and that something could be done in the way of relating observations and experience gathered in the practical conduct of works.

Your studies, such as this institution is to promote, must of necessity relate to particular methods and exact treatment, must come within the domain of computable quantities, and be governed by rules that are constant, or nearly so, while the management or administration of works must be empirically learned by observation, inference and analogy, not from one alone, but from many persons and in many places.

This being the case, so much as can be presented here in the form of lectures must be the result of experience and observation, and accepted as such. It is true that one may by logical inference

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arrive at conclusions and methods of management, and it would be better if more was learned in this way, or that opinions were qualified in this manner, and in that view some attempt will be made to analyze certain things as we go along.

You have an advantage here not enjoyed so far as I know by the students of any similar institution in this country — that of an instructor who has himself been a work's manager, and is able to follow the problems here treated to their ultimate application. I may also mention this qualification as a succession, and perhaps to some extent an inspiration from one of the most successful teachers of constructive engineering that this or any other country can boast, Prof. John E. Sweet. "Sweet's boys," as they are called, always found something to do when they "went out into the world," as he termed it, and there is this encouragement in the scheme of lectures on shop management that the reputation of Sweet's boys grew out of his attempt, in a greater degree than ever before or since, to teach application and administrative matters. I say administration, because in most cases an education here, or in other institutions of the kind, is pursued with reference to directing and planning the work of other people, also as a stock in trade, so to speak, to be balanced against money, capital, and in other ways, but always involving management of some kind.

This art of management is unfortunately a subject that by its nature is personal, and for that reason concealed. A great share of it is confidential in respect to a works or a business. It includes to some extent methods and processes, that is, methods and processes personal to a manager, or peculiar to himself, invented we may call it, or regarded in the light of invention. This is proved by the fact that the power of management is in business in a sense considered separately from skill, or even technical knowledge, and, as every one knows, constitutes a valuable consideration in the hands of any one who has made a success in this way.

A successful foreman is an example of this. The ideal foreman is a mythical person, who is presumed to be able to do almost anything, and to be responsible for everything. He represents the owners, or the head management, and also to some extent the men whose work he directs; thus occupying a position of exceeding difficulty, inconsistent and nearly impossible on logical grounds and in fact. Of this matter of foremen more will be said in a future place. It is presented here in illustration of the difference between technical knowledge and administration and the value of the two when combined.

A pride in personal or peculiar methods is as wide as mechanic art, and is not to be disparaged, on the contrary is among the strongest incentives to develop the art of management, but such pride and confidence as you may readily infer becomes a bar to common knowledge of the manager's art. Owners, managers, superintendents and foremen are always ready to converse on general matters connected with their business, and of all that can be compared, estimated and written in books, but, as before remarked, there is a conciousness and intent of keeping back a good deal that has arisen out of particular experience, and this is not to be wondered at.

No one wants to state what they know there is no means of proving, and what has no grounds of conviction in their own minds. Empirical belief is always timid. A man may say, "I bore all holes with bars, do not use involute teeth for wheels, maintain standard sizes by means of turning mandrels, paint my machinery with lusterless paint, and do not indenture apprentices," but he does not regard these things as absolutely right, or expedient in all cases, because others whose practice he must respect do not do these things in his way, so there is a doubt and want of confidence that leads to reticence.

Pursuing these general or introductory remarks a little farther, the absence of fixed methods, rules and exact knowledge of management must always make it experimental. As in the case of a foreman, an ideal course or plan is impossible, because methods must be adapted to circumstances that exist in a works. The owners, head manager, workmen, and even the public around, have ideas of management and methods, and these ideas are apt to be like a good deal of other assumed knowledge of the kind, inversely as the amount of understanding in the case.

This is a peculiar trait of human nature. The person who has acquired barely the rudiments of any skilled operation is sure to imagine himself an adept. Bigoted people are almost sure to be unskilled, and this cannot be helped, so that one of the most difficult parts of shop administration is in understanding and carefully dealing with existing methods. I will relate a circumstance to illustrate this.

Some years ago I was called out to England, partly to assist in preparing plans for some special machine tools required at the Elswick Works of Sir Willliam Armstrong & Co., at New Castle on Tyne. On going to New Castle I found a great strike going on at

the Elswick Works. More than a thousand men had quit work by reason of a disagreement in the forging department—a very important branch in these great works, which occupy in all one mile in length, on the bank of the River Tyne.

There was good opportunity to study this strike, which arose from a change of managers in the forging department, a Mr. O'Donnel, of Dublin, with whom I was well acquainted, having been recently installed in charge of the forges and connected operations.

Mr. O'Donnel had been in a high position before, as locomotive superintendent of the Great Southern and Western Railway, of Ireland. The railway works are situated at Inchicore, Dublin, and some explanation must be given for the reason of his being appointed at the Elswick Works.

Inchicore is a kind of normal training school for mechanical managers in Great Britain. From there comes a great many of the railway mechanical superintendents, because nowhere else has there been so much attention given to shop methods; besides, the men trained there are of high natural ability.

Inchicore is a kind of retired place out of Dublin some distance, where the pick of young men in the city find their way. There are wonderful coöperative and other provisions there that will come up to be more fully explained in a future section of these lectures.

In the forging shop there has been a development of "die forging" more elaborate perhaps than in any other works of the kind in the world. The dies, most of them, are merely matrices of cast iron or cast steel, two parts connected by a bar of spring steel bent into **U** form and attached to the two dies to hold them in "register," and permits the dies to open by the springing of this bow handle, to so call it. The blanks when heated are laid within these dies, which may be likened to waffle irons, and are placed beneath a powerful steam hammer that comes down and closes the dies by one blow, shaping the iron or steel just as any soft material, like putty, would be pressed into form. The surplus metal flows out in a fin, to be trimmed off around the edges.

Sir William Armstrong, or the Directors of the Elswick company, were aware of the economic effect of this "spring die" forging system, as it was called, and employed Mr. O'Donnel to carry out this with various other improvements at the Armstrong works.

For a generation at least the "hammermen" at New Castle had gone on in a routine of method supposed to be perfect, or at least traditional, which is sometimes construed as the same thing in those

old countries, and no one dreamed that a change was expedient or possible.

The leading men made large wages, more than you will suppose possible in that country, They had inherited the business from their fathers, and were amazed at a proposition to introduce changes, consequently "went out," as they called it, with a large number of men in other connected departments, amounting to more than one thousand, and at one time nearly two thousand.

The strike was in a sense friendly, that is, conferences were held with the men, and Mr. O'Donnel found himself in a difficult and trying position. The directors of the works had their faith shaken by the views of the striking hammermen, but a ruse set the whole thing right.

On reaching New Castle I called at Mr. O'Donnel's office, and he explained the situation, at the end of his remarks pointing to a table near by, covered with a cloth, and said: "there is the argument that will sustain or defeat me."

He removed the cloth, showing a collection of small forgings of various standard patterns used in the works. On each was a ticket giving its weight, the price of forging at Elswick, and another unexplained figure alongside. These forgings had been made at Inchicore.

He had the table moved to the director's room, where a meeting was held that day, and when he was called to be consulted he requested that the examples be examined. They were pronounced marvelous and perfect by every one, and on inquiry as to what this meant, Mr. O'Donnel said: "I am authorized to say, on behalf of the directors of the Great Southern and Western Railway of Ireland, that they will furnish and deliver here at your works as many of these forgings as you require, at the prices marked on the tickets."

This settled the matter there. The prices were only half as much in some cases, and much less in all than was being paid at the Elswick works. Mr. O'Donnel called the men together, told them just what he had done; explained the methods, also that his object was to cheapen production and not to reduce wages; that under the present methods, if persisted in, there would soon be neither work nor wages. The men went to work on the new methods, and a year later, as I have heard, presented Mr. O'Donnel with a friendly testimonial of their confidence and regard.

This dispute was much wider and more important than this single circumstance indicates. There were many other things to man-

age besides die forging, but by proper management all was in the end settled amicably and profitably.

The purpose of this story, related at some length, is to show that the new manager's knowledge of forging processes, or other technical knowledge of his, was not the main element in the case. He had to prove his position, gain confidence, both of the owners and the workmen, arouse emulation and establish good will, which was a great deal more difficult of accomplishment than the die processes.

MANUFACTURES ON THE PACIFIC COAST.

As this first section of the proposed lectures will be of an introductory nature, dealing mainly with the nature and objects of the subject to be treated, it will be proper to say something further of the importance of administration and its relation to active industry.

On this Coast has been founded or projected at some time almost every industry known to the technical arts. Some of these attempts logical, some otherwise, and of all only a few have succeeded well. This remark is true of most any other place, but not in the same degree or under the same circumstances as on this Coast. People come here from the Eastern States, and from all parts of the world, attracted by the promise and opportunities that are supposed to exist in a new country, but mainly because of the climate and physical peculiarities of the Coast that have rendered it famous. At first they came to mine gold, or to participate in the circumstances which gold mining produced. These people brought with them knowledge and experience in nearly every art known to human skill, and when here, and the period of speculation passed away, they naturally looked about for permanent pursuits.

A great many come now for their health, or to avoid the rigor of winters at the East. They cannot remain idle, and naturally set about the business with which they were acquainted in their former homes. This, as before remarked, has led to the founding at various periods, of nearly every kind of skilled industry, from making watches and jewelry to steamships, and from silk fabric to gunny bags.

Some of these industries have succeeded, more of them have failed, and when the cause of the failure is inquired into, a long train of causes is set up, some of them reasonable and sufficient, but in most cases neither. Among these reasons of failure, which need not be enumerated, one rarely ever hears of management or admin-

istration, still among all causes of failure this is undoubtedly the most common one, either alone or associated with others of less import.

Some years ago I asked Mr. Calvin Brown, the well-known civil engineer of San Francisco, why the 300,000 barrels of hydraulic cement used on this Coast were not made here, and if the natural elements did not exist? His answer was that the required elements did exist here, except one, which was management of the manufacture, that the material and processes of production permitted a reasonable profit, but there was no regularity in the cement produced, and a want of confidence in its uniformity. Mr. Brown was the first engineer on this Coast to erect concrete work, when he was in the employ of the General Government, and was also, as I believe, the superintending engineer who constructed some of the cement works founded near Santa Cruz, in this State. He is a recognized authority on this subject, and his calculations were, no doubt, made to include all the economical conditions involved in the manufacture.

Not satisfied with this explanation I submitted the matter to Prof. Louis Falkenau, an analytical chemist of San Francisco, a man able in his profession and thoroughly acquainted by both education and experience with the resources of the Coast, all of its minerals and the economy of manufactures. His views corresponded with those of Mr. Brown, and he also claimed that the failure of this important industry was due to a want of a technical and commercial management of the works founded.

Now assuming these views of the matter to be correct, and even that the impediment is now removed, the misfortune of the matter comes up in another form. Capital is frightened off, and no one with this history before them will engage in the manufacture of hydraulic cement.

The force of this illustration would be greatly increased by adding various facts that have been related to me in connection with cement manufacture on this Coast, but as no new ventures of the kind have been made in the fifteen years I have been here, these facts are not reliable enough for recountal at this time. Every one, so far as I know, admits that good cement was made, but as one man expressed it, "no barrel had two ends alike," meaning that there was no uniformity in the process, and no exercise of the intelligent painstaking care required in what is an intricate process, demanding not only complete chemical and technological knowledge of the art, but an intense application of these, and the handling of men unused to any work requiring precision.

Any one desiring to investigate this matter further will find some account of it in a paper on the subject, by Mr. Calvin Brown, read before the Technical Society of the Pacific Coast about five years ago, and published in the Transactions of that Society. Some time, let us hope soon, this manufacture will be founded again, and prosecuted to a successful issue.

I happened to be in Sweden when this same manufacture was founded there, and many times have thought of the difference in methods. It is not to draw invidious comparisons, but is relevant to the subject under discussion. Sweden had been importing a good deal of Portland cement, and when the subject of local manufacture came up, the best-informed chemists in the country examined the natural material existing there. Experiment and careful calculations were made respecting fuel, transportation, labor, and every thing of an economic nature was considered by merchants and engineers. A cement works was erected near Gothenberg, and the King of Sweden, Oscar II, came down to attend the opening of the cement works.

This monarch, unlike most others, thought it worth his while to learn industrial as well as military science, and enjoys, as I believe, the distinction of being the most learned man that occupies a throne at this day. He mounted an improvised platform in the works at Gothenberg, to address the people, and in addition to reviewing the commercial importance of the scheme, gave a history of the manufacture, describing the whole technical details of elements, processes and uses. Capable and careful men were put in charge, and I have no doubt the industry is going on now in a prosperous manner. From the inception of the scheme there was complete administration, and unless there were errors in the original computations there was no chance of failure. The circumstances related happened nearly twenty years ago.

In the older countries, where trained skill is more highly estimated, and where consulting engineers are more commonly called in, and, I may add, where all the conditions of manufacture and construction are more cautiously considered, the failure of enterprises is rare and also is serious. We have many lessons to learn from their longer experience, especially as our future must in many respects lie along the same road.

ESTIMATES FOR WORK.

Proceeding now to a more practical consideration of the subject of works administration, the first thing to be considered in this, as in all human activities, is, what are the main objects in view? This

lets us down from the ideal to sordid ground, and the answer must be "commercial gain." It is a most unromantic conclusion, and is perhaps not quite true, because human pursuits, besides providing for our physical and material wants, also provides an agreeable field for the cultivation of our faculties and the pleasures of accomplishment, but construed in the abstract, the primal object of industrial pursuits is commercial gain, or, to reduce it to lower terms, is an attempt to produce commodities at a cost less than the price they will sell for.

This is a bald qualification, but it must be kept in mind as an objective point in each and every operation that we call productive industry. This being the case, and as the cost of commodities comes before their sale price, we will first consider cost. In this little term of four letters lies a potency that consumes the highest ability of our ablest engineers and mechanics.

It will be difficult to realize what this includes in a works; and you will no doubt be surprised when I say that a principal work of Mr. Dickie, Manager of the Union Iron Works, who recently lectured before you, is to ascertain and inform his company of the cost of producing work. This work of estimates compasses the whole range of constructive engineering work, the natural properties and adaptation of material, its cost, all the methods of manipulation, the expense account, engineering service, risks of all kinds, and contemporary values.

I have known Mr. Dickie, who is an engineer of the highest standing, and with a charge as responsible and difficult as is filled by any one in his profession, to shut himself up for months in his private office to find out the cost of producing a warship. When done this cost, set forth in thousands of items, filled a book as large as a merchant's ledger, and a hundred times more intricate, because the work involved to a great extent both methods and design.

This work is called estimating, and is the first process in undertaking work, or, as we may say, the first step in the practical conduct of a going works. There are usually in the corps or staff of a works plenty of men who know how things are made, how sold, and how collected for; how material is bought, stored, handled and cared for; how drawings are made, weights ascertained, and all this, but the prime cost derived from the assembling of all these things, with the "allowances," margins for error, changes of prices, the facilities for production and so on, calls for the highest ability.

Twenty years of experience has in the case of Mr. Dickie, and

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EXPENSE AS A COMPONENT OF COST.

(CONTINUED.)

The expense element is a flexible one. It includes rent, light, heat, water, insurance, travelling, drawings, accounts and records, office service and management other than immediately in the constructive departments. Expense may be classified by the rule that it includes whatever disappears, and has to be continually replaced or reproduced; also as whatever is not sold. Or to qualify it more plainly still, whatever is not converted into merchandise and is not sold. In the works, sand, oil and files are expense, but paint, packing and screws are merchandise, and I will here mention that the separation and classification of the various supplies for a works into merchandise, expense, implements, and so on, is a very interesting and useful exercise.

As accounts are commonly kept in machine works, and they are typical of all kinds of manufactories, the charges to expense are from 15 to 30 per cent. It is, as has been said, an indeterminate quantity, depending in a great measure on the means employed to sell the product. For estimates it is commonly assumed from precedent or former records, an average being taken over previous years, or by analogy to similar business of like nature and extent.

Expense varies with the volume of business, but not directly. It is least in a very large and in a very small business. A very small business is sometimes carried on with the expense account

almost eliminated. To extend a large business does not call for a proportionate amount of highly-paid service, and the expense of all elements fall off in greater or less proportion with an increase of volume. Material is purchased cheaper in proportion to quantity. A cargo of coal, iron or timber is bought cheaper than a car load, and a good deal cheaper than a wagon load; besides the handling and storing of a large quantity is cheaper than for a small quantity if charged against the volume or amount.

Steam power does not occupy room and require attention in proportion to horse power, but it costs less in both of these and in other respects as the capacity is increased. It will require the work of one skilled man to manage an engine of twenty-five horse power. Sometimes one man will manage and care for an engine and steam plant of one hundred horse power, but it does not require four men for four hundred horse power, or ten men for a thousand horse power.

It costs nearly the same to advertise a business of fifty men as it does for one of five hundred men. For example, if we assume that the expense element in production follows inversely as volume or amount of product, small shops could not exist. They would be eaten up by the expense account. But small shops do exist, as we all know, and sometimes persist in existing when the larger ones fail, and it will be almost an anomalous proposition to say that this very expense account gives them a tenure of existence and a chance of success.

While it follows upward in some proportion as before named, it does not do so from the beginning or from a small shop, but from an aggregation that may be called a works. The unit is of course the work of one man, and, as we all know, one man makes up the working force in many kinds of operations, as in watch and clock repairing shops, dentist offices and country blacksmiths. Sometimes in a small machine shop one man may carry on a small business with his own work.

The dividing line from which an expense account seems to diminish each way is where the division of labor and processes begin; in a machine business when a clerk, draughtsman, smith and foreman are required, or, as we may say, for most kinds of manufacturing operations when twenty or more men are engaged.

With a small business, tapering downward, so to speak, from twenty men or so, the expense account begins to drop off. Advertising, draughting, superintendence and other expense elements are

avoided, picked up, or added to other service, often contributed outside of working hours. All of our industries were once carried on in this small manner, and however impractical and inexpedient it may be now there was much to commend it in respect to certain social relations it brought about.

In the older countries the system of segregated industry, watch making in Switzerland, for example, many industries at Birmingham, England, and in the northern cities of France, certainly led to many features of social life that are impossible under the factory system. These results are to a great extent exemplified in the agricultural pursuits of our own and all other countries at this day.

As, however, ethical matters do not belong in the present connection their discussion can be left to a future place, when methods of discipline and the social relations between owners and the workmen will be considered. But without wholly leaving the present subject of the expense element in manufactures we may proceed to inquire a little into the causes that have so completely changed the methods of industry to the factory system.

THE FACTORY SYSTEM.

Chief among these is motive power. When operations of all kinds were performed by hand, a few men, or even one man, could work independently, but when power operations were introduced it required a considerable volume of business to warrant the maintenance of a steam engine or water power, so it became necessary to increase the size of works, and when increased from this cause up to what might be called a full works a further increase was demanded to diminish the expense account and other elements of production.

Another cause of aggregation was in implements. An expensive machine or tool may be required for some operation, and to provide such a tool without loss it requires to be kept at work. This is true of a great many implements, and unless kept at work they slide over into the expense account and eat up profits at an alarming rate. It was this fact more than any other that brought about tool combination and combined machines, which is to form an important part of these lectures when we come to manipulative processes.

Another and principal cause of aggregation in industry, or the factory system, as it is sometimes called, may be noticed here, especially as it has a direct bearing upon the expense element in manufactures, that of the division of skill on the grounds of dexterity. This matter will never be better or more ably presented

than it was a century and a quarter ago by that remarkable man, Adam Smith, who, in his *Inquiry Into the Wealth of Nations*, used the manufacture of common pins, as then carried on, to show the effect produced by a division of skill.

At that time pins were cut from wire, the points were formed by hand, and the heads made by means of open collars bent to a circle and forced on to form a head. One man performing all these different operations could make only a few dozen pins in a day, but when one man cut off the wire, another pointed the pieces, a third coiled the heads, and a fourth put the heads on, the average production by reason of special skill was increased five fold, and the cost was wonderfully reduced in this way.

There are, however, many reasons for the aggregation of industry, too many to be mentioned even, but at this day one of a potent nature, quite unknown a quarter of a century ago, is that of extensive combination between works of one kind or class with a view to monopoly, but generally under the pretense of reducing the expense element in manufacture.

I have merely touched upon some of the conditions that affect expense, but have presented enough no doubt to show its complexity. The rest must be left to your own investigation, with the assurance, however, that while the expense account in a particular business or establishment may be very nearly determined, there is no set rule that will cover all or even many cases.

There is a rough rule for determining expense and profit together, followed in a large number of cases, that applies in machine shops making a miscellaneous line of work, a kind of lazy man's rule, but convenient withal, and much better than no rule at all. It is that of adding a percentage to the labor account to cover profit and expense. A common way is to double the wages account, and add it to the material to make up prime cost and profit. Material bearing what we call a fixed component, and labor bearing a very constant proportion to expense, it is evident that a rule of the kind above named will answer tolerably well in average works, but for any kind of regular manufacture in which commodities are duplicated, and this is the only kind of work to which the term manufacture applies, the amount set off for expense and profit by this rule is too great.

When there is kept a net or specific expense account to cover certain things, estimating the cost of work becomes more difficult, or rather is more extensive, but is more exact. In some works, especially large works, the expense account falls as low as fifteen

per cent. of prime cost, that is, the components included in this account do not exceed fifteen per cent., and a good many things properly expense are charged under other heads. Among such items, and especially in this country, is the use and maintenance of capital. Use meaning the interest on investment, and maintenance the assurance against risk. Both these things will be considered under the head of capital in a future place.

One reason for lumping labor, expense and profit in one account for the purpose of estimating, is the difficulty of determining what net labor cost or wages amount to. It is customary, as you all know, to furnish workmen with what are called time tickets, on which are entered each day the hours and fractions of hours the men have been engaged on certain jobs in the works.

The sum of time on these tickets is made up by the clerks and charged to the different jobs, also compared with the time roll or general time account and wages account, so that when any work is completed it is easy to make up the exact amount of wages paid out for the work, but the amount thus found will not do to enter in a prime cost account. There are a good many things to add to it. Among these are management or superintendence, accidents and mistakes, inefficiency, apprentice work, holiday privileges, and other things that properly belong to the labor element, but may be, as before explained, included in an expense account.

THE RELATIONS OF SKILLED LABOR.

The labor component in skilled production presents at this time the greatest social problem that has ever confronted the world. Previous social problems that have led to the slaughter of thousands or even of millions of people, and have destroyed and upraised States and Empires, have always had their root in oppression that denied physical comforts and rights to laboring people, but now the problem has assumed a new phase, and is argued upon the rights and relations of labor compared to the rights of investment, commercial skill, and the division of profits.

It will not be proper to include in these lectures a consideration of the social and economic relations of skilled labor. The subject is too broad, and far beyond the powers of any one to discern and explain at this time, but it will be proper to treat upon the technical causes, they may be called, that lie at the bottom of labor disturbance in skilled industry the world over.

These causes lie mainly in the works, or in the working rela-

tions of men, we may call it, and rise out of the labor component in production, how it is managed and paid for. In the first place, and as the main fact of all, must be considered the altered relations that workmen bear to the processes of production and to their employers. It is not very long ago that skill meant manual dexterity and empirical knowledge. The consideration returned for wages was manual skill, qualified by experience. A man was much like a machine, capable of higher powers to be sure, but his main functions were those of a machine.

This placed the workmen in the social scale next to the slave, where he remained for centuries. The master did not own his person, but owned his time, which was paid for by the day, week or month, without any defined or definable measure of what the workman should do for his wages. The incentives to work were his sense of honor, necessity of his wages and the fear of losing his employment. Not very high incentives one may say, but all that exist in a time-pay system, yet prevalent all over the world, but no doubt to end before very long in a more equitable and logical relation between skilled labor, capital and community.

Time labor, or the employment of men's time in productive work, or in work determinable in the terms of production, is an anomaly. The things employed are not only manual and empirical knowledge, but also, and in many cases mainly, inductive and deductive mental skill ranking with or above the commercial conduct of a business.

Men are no longer machines. We have the machines separate from the men, and employ the latter to contrive and direct the machines. This in skilled industry places workmen in a new and higher position socially, or should so place them. But there is one impediment to this, one that is not commonly known or recognized, that of the slowness with which all social changes take place.

A period of fifty years has been enough to change nearly all the processes and methods of manufacture, calling for an entirely new relation of workmen to their employers and to community; but fifty years can work but little change in social relations. It is not two generations, and there are men living now and working who were reared and learned their art under circumstances that have passed away. The progress made by science and in the mechanic arts has no such limit of time. In ten years the change is more than a century can produce in the social relations of men. Science and discovery outrun social change in such degree as to prevent comparison, hence the unrest and disturbance abroad in the land.

Looking at the problem practically it may be observed that each year, each essay, and each investigation brings us nearer to the fact that time work must cease in our skilled industries. Down to a few years ago no one had perceived this. The existence of some disturbing cause was plain enough in the discontent and demands of labor, but the real cause was not suspected. Various schemes of a paternal nature, such as profit sharing, were and are still urged as a remedy for labor disaffection, and in some cases, when carried out in good faith, have been successful in so far as preventing strikes, but such means are only palliative so long as labor is paid by time and workmen are not made responsible.

In this term "responsible" lies the secret of the whole matter, the distinction between slavery, time service, and contract service. I will attempt to make it clear by means of the internal relations of a work shop, and must remind you that it is a very practical question that you will find is one to be dealt with in a serious manner, and very soon in this and all other countries where skilled industry is carried on.

To prove the pressing nature of this problem, I need only refer you to the department in the principal technical journals of England, embracing from one to three pages in each issue, under the head of "Industrial News," and to the existence of labor bureaus in at least a dozen States in this country, and a National Bureau, at Washington, devoted to the same subject; also to societies formed to promote means for the avoidance of labor dissensions, and the publication of a journal directed to profit sharing with many other panaceas for labor disturbance.

As before remarked, we cannot enter into the ethical, social and economic phases of the labor problem, further than it is connected with works administration and the practical conduct of industry, but this will be a good way, because it is to be questioned if all the writing, speaking and philosophizing about labor relations for the past ten years has done so much toward a solution and settlement of the problem as a single one out of a number of shop experiments made in this and other countries.

Of particular cases we will speak farther on when some previous consideration of the subject will prepare us to understand the nature of the experiments made. To begin with, we may classify skilled service under four heads:

First.— slavery, where the workman is wholly irresponsible.

Second.— time service, where he is partially responsible.

Third.—piece work, where he is responsible for his own work alone.

Fourth.—contract work, where the whole working force is collectively responsible.

Now these four methods or systems of service have the measure of responsibilty named, from nothing to all. Responsibility is the key to all human actions that are voluntary and not a sequence of necessity. This proposition may seem a strange one, but it is certainly true. Whether it be a cause or sequence, or both, we need not stop to inquire so long as we find it the constant characteristic of contented and efficient effort on the part of those employed.

In respect to slavery, that no longer exists as a provision of law in any country where skilled industry is extensively carried on, and we need only to refer to it in illustration. The slave is not responsible for the product of his labor. It may be more or less in proportion to what his master gives in return, but personally the slave is not responsible, because not a free agent. Emulation, respect, and a sense of duty may in a limited degree enter into his incentives, but the subordination of his will and fear of punishment, are the main causes that enforce service. The system has happily passed out of the world in so far as pursuits involving skill, not as a deliberate policy so much as by the force of circumstances. I am old enough to have seen a good deal of it in this country, and learned some lessons that may unconsciously enter into views now being laid before you.

Time work, wherein the workman is paid for a term of service, yet the most common form of employment, stands next to slavery. Not near to it perhaps, but next in the movement toward responsibility, and is practicable only because of a sense of personal honor and of justice due to the high degree of civilization existing in countries where skilled industries are carried on.

Workmen under this system are responsible so far as their sense of honor and emulative pride produces responsibility, but no farther. A man is hired by the hour, day, week, or month, but the contract is indeterminate. If he spoils his work or fails to render such service as common custom demands, he can be discharged and nothing more. If he spoils work or fails by incompetence to earn his wages and a profit for his employer, it makes no difference, the law will give him his wages irrespective of everything but wilful negligence and the malicious destruction of his employer's property.

What a remarkable compliment to the integrity and good faith

of the skilled workmen of our time! Contrast it with the usages of common trade. If exchanges were to the same extent based on good faith and manly honor, would a like result follow? I am not claiming that faithful service is always rendered from honorable and unselfish motives. The penalty of discharge is always present, and the sentiments engendered by unions or trade organizations are often independent of any interest in employers or of community outside of the union, but we can only wonder that the circumstances are not worse when the nature and manner of controlling service by time pay are considered.

EXISTING METHODS OF EMPLOYMENT.

The present extent of time work in skilled industries is a strong argument as to its necessity under modern circumstances, but it is not universal, and is constantly becoming less so. Greater progress would have been made toward a better system long ago had it not been for the strong efforts that have been made toward paternal systems, such as profit sharing, by earnest and philanthropic men in most cases, but mistakenly in so far as meeting the real causes that lie at the bottom of labor dissension.

Such a proposition as this needs some defense, and in that way one may ask, what have workmen to do with profits not earned by their efforts and skill? Only a part of the profits in an establishment are thus earned. They depend on a good many things beside faithful and efficient labor, and if profits not so earned are divided with workmen, it is a gift or bribe that destroys independence and responsibility. Workmen of our day do not want such favors. What they want and need is justice, fair dealing and responsibility for what they themselves perform and produce. They have as much reason to risk their labor as an employer has to risk his capital, service, management and implements, and all that is wanted is to segregate the labor component, and let it rest upon its own responsibility, and do away so far as possible with a time system of service. It is degrading in the skilled industries of our time, and while it cannot be at once removed, a beginning can be made, and above all we can study its nature and effects in the labor problems now convulsing the industrial world.

Next we will consider the piece work system, by which is meant personal contracts with particular workmen — a mixed system in which a part of the working force is made responsible, and the rest is employed on the time method. This is a bad system in many

ways, condemned by the trade unions for many reasons. In the first place it is discriminating and unequal, and secondly there is no impartial standard from which prices can be determined. The rate is a matter of chance, depending on the whim, choice or conscience of the employer. It is a provincial idea, so to speak, and is a crude effort toward a contract system. It increases the responsibility of workmen without adding to their independence, does not succeed unless very carefully adjusted, and is unnecessary.

We are well aware of the extent to which it has been carried out in various shops, especially in New England, but if one will look into the matter carefully it will be found that wherever successful, there has been some features of a contract system involved that modified discrimination among the men, and that rates were not fixed by accident or independently in each shop. It is an undemocratic idea, not consistent with the spirit of our times, and will, no doubt, pass away for something better in the future; not very soon, perhaps, because these customs are tenacious.

The next system of service, if that term applies, is what has been called the contract system, or as we may call it, the responsible system, in which labor is set off as an independent element in production. This will consume some time, and is well worthy of it, because there is no one here who will go out into the activities of the industrial world without having to face and deal with the labor problem. It will be discussed widely, and press more and more for solution, as education and competition goes on.

The conflict between capital and labor, that many prophesy, has no grounds in fair inference, if reason and fairness are permitted to enter into the controversy. To assume anything else is to accuse skilled men of being vicious, unfair and ignorant; also is to accuse employers of being dishonest and illogical. There is no need of a labor war in the sense of violence, or even of disturbance of our manufacturing industries, to which labor dissensions are now principally confined.

To make clear what is meant by a contract system of labor, the best way will be to illustrate it by an assumed example, and as one class of manufactures is as good as another, one of the most familiar, a joiner works, will answer the purpose.

In a factory of this kind is prepared all kinds of timber, house furnishing material, such as flooring, ceiling, doors, sash, frames, mouldings, and so on. All these things have regular prices, because made very uniform for average houses, and there are price lists pub-

lished that apply over wide districts, and for some things, like doors, sash mouldings and flooring, the lists apply to the whole country within reasonable distances of transportation. The work, when not included in the price lists, is made to estimates in which the labor is always made up as a separate item, and the labor in listed articles is either known or ascertainable in all establishments; is better known indeed than the other elements of material and expense that must be included in estimates.

Suppose then that a joiner works is to be established, and the owners instead of hiring men by time to do the work, establish a contract system for the labor. The men are employed as in any other case, and are permitted to draw a certain amount of money each week in proportion to the usual wages paid in such establishments, but are informed that work is all contracted to the men, or to the shop, as we would say, and whatever money was advanced for wages would be deducted from the sum due at the end of the week or month for work turned out. The men being apprised of or already knowing the rate for making standard work, no difficulty would arise from this, and as all irregular or special work would have to be estimated and include the element of labor, that amount could be posted in the works, or entered in a book kept by the foreman and accessible to the workmen. Each man would, as is the present custom, enter each day on his time card the number of hours engaged on different jobs, which would, as is also the custom in most places, have a catalogue or order number, that would be entered on the tickets, with the time given to that number or order.

The whole shop is now working on the contract system. Every man, boy and apprentice is included, and at the end of a month, a week, or at any other time convenient, the completed work is made up and compared with the amount paid out in advances to the men. If there is a balance due them it is divided pro rata among all in proportion to their rank as indicated by the weekly or daily wages on which the advances are made. If there is a deficit the men must make it good by a corresponding reduction.

All losses by accident, carelessness or inefficiency of the men should be made good to the firm or company, and all losses chargeable to the owners by detention, want of material or implements, or accidents due the plant, would have to be made good to the men. If a man seeking work represents himself falsely as to his skill or rank, the owners need not concern themselves about that. The men in the works will attend to that matter, because if rated above his

capacity he would be imposing on all the rest, and lowering their wages.

The establishment would be coöperative, divided into two departments or interests closely allied and interdependent. The workmen would have nothing to do with profits, risks or capital, except to help sustain these as a foundation for their own part, the labor, and their profits would depend on their own efforts and skill. No foreman to watch the men would be required. They would do the watching themselves, and do it in an effective manner. Drones would be weeded out, or what is more likely, they would be reformed, or not exist at all under such a system. The working force would be independent, interested and responsible. If a man needed assistance or favor, the whole force could extend it by giving him easy work, or in other ways. It is an ideal system, but would be pronounced by a good many impracticable, and as some answer must be made to objections I will begin by an illustration.

Many years ago I had the misfortune of attending a political convention composed of all kinds of people, all of whom were presumed to understand laws, legislation and the general conduct of the Nation. The chairman, as now remembered, was the keeper of a livery stable, a loud, positive man, who was emphatic and final in his rulings. Some one moved the previous question and cut off debate in some motion that was passed, but a member arose and protested that under the circumstances this could not be done. The chairman arose in his wrath, and said: "Why, you ass, it *has* been done."

This applies to the contract system of labor. It *has* been done, not in one instance, but in hundreds of cases, and thousands of men are working on this method at this time. Not only this, other systems with a similar object infinitely more intricate and difficult have been in use for years, as witness the paper of Mr. F. W. Taylor, of Philadelphia, on "A Piece Rate System of Labor," read before the American Society of Mechanical Engineers, at the Detroit meeting in June of the present year.

I may also refer to an essay of my own, prepared some months ago for the editor of the *American Machinist*, and republished in "INDUSTRY" for January and February, 1895. In this article are a number of facts bearing upon the contract system of labor, also an explanation of it much fuller than the plan of these lectures will permit.

It must be admitted that a good deal of time and education would

be required to introduce the system. All changes that affect the social and economic conditions of people come about very slowly but certainly if founded in expediency, justice and proper objects. The impediments are many, and not to consume more time here it is suggested that objections handed in will be answered as well as possible at a future lecture.

One more thing in this connection; the most important of all, indeed. What would be the effect of a contract system on strikes and labor dissensions? The answer will be found by searching for causes of dissension in such a system, and the circumstances under which a strike or quarrel could occur, and it will be hard to find or imagine. There has to be various things settled, as experience has proved, but there is no difficulty in that, and here again I must quote the chairman of the political convention. I have had the honor to sit as judge in cases of dispute under the contract system, and must admit that the duty was congenial and easy. The thing *has* been done. No class of men in the world are so amenable to reason, logic and common fairness as mechanics. Their calling demands the continual exercise of reasoning powers, and is devoid of sophistry, deceit and cunning, common in many other callings, such as small trading and trade soliciting as carried on at this day. This I assert on the authority of an experience of thirty years in the works, all the time in charge of men, and an inability now to recall in all that experience a single case of unreasonable demands, a strike even, or other trouble that led to the loss of so much as one dollar.

MATERIAL AS A COMPONENT.

It may seem tedious that in all this time we have got no farther than estimating and prime cost, but these are very important matters, are indeed the very foundation of successful administration of a works, hence must be carefully gone into.

The third component, material, need not detain us long. It is an element that is to a great degree determinable by simple means in so far as value or price, the two qualifying conditions being cost and waste. There is also in the matter of material wide problems of an engineering nature, but these have been so ably treated here by Prof. Smith, and laid down in his writings on the subject, that in so far as metals it is only necessary to refer to his treatise on "The Materials of Construction," published here in 1893.

The economic problems are quality and waste, and the first is so nearly the same as adaptability that we may assume that this too

is included in Professor Smith's lectures. Wastes are determinable by records. By waste is meant what is cut away by cold shaping, by oxidation, and other losses, also in moulding; is the difference, so to speak, between the stock-room and warehouse weights.

The wastes in wood, iron and steel are between ten and twenty per cent. in machine construction, when there are fitted and finished parts, but as estimating is usually done on gross weights, or should be so done, there are no allowances except for spoiled or broken parts. By no allowance is meant special allowance, because in estimating, the weight of a shaft for example, the contour or rough dimensions are assumed, but if the shaft is ten feet long, and if the bar from which it must be cut is twelve feet long, there is a waste of one sixth, less the scrap value of what is cut off. The piece may be used for some other purpose, but it must be stored, remembered and probably cut again. To weld such pieces will cost the difference between their value in a bar and as scrap, so it is waste at any rate, and should be so regarded.

These remarks, which are only in illustration, are preliminary to suggesting that in estimating for common machinery there should be added about five per cent. for the waste of material, counting from prepared castings, from metal in bars, and other material in corresponding condition.

The methods of arriving at the amount of material consumed in work are various. A common one is to weigh in all kinds of material as it is used; another is to weigh the completed work, add for waste, and then make up separately the brass, screws, lining metal and so on, and deduct these to find the weight of frames, but on the whole it may be doubted if any rules that could be given here will have much value. The matter should be left to the judgment and ingenuity of each person to work out in their own way. One thing, however, may be noticed, that is the method of computing weights, or rather the "habit" of computing weights, because the method is a kind of mental mensuration that enables one to guess very closely the weight of a structure of any kind.

In England this work of taking out weights has become a special calling, done by what are called "quantity clerks," who become so expert by the use of rules, tables, implements and memory that weights are arrived at with great rapidity; so also other things, such as the amount of work involved, computed from the surfaces turned, bored, planed or finished, the number of screws, nuts, tapped holes, rough drilling, and so on.

I was present same years ago when Prof. Hesse, of the University of California, was called in to examine the armature of one of the first alternating dynamos sent to this Coast, which went to pieces, cutting off beams, going through walls, and smashing various things in the plane of its rotation. The parts were hunted up as far as possible, some of them being found in an adjoining enclosure across the street. The manager of the works proposed to weigh them, but Prof. Hesse said: "That is useles, the weights arise out of dimensions, and will be found easier in that way."

A good way to manage for rough weights is to have castings and forgings weighed and marked as they leave the smith shop and foundry, and the weights charged to the work in process. This is essential in a works where the labor is performed under a contract system, because the machine-shop weights must correspond to the foundry weights, which are paid for by the ton, with a division into classes.

In the management of a works of any kind the principal thing about materials is to have them at hand ready. It is hard to impress any one, not experienced, with the importance of this, and it would be incredible if there was some way of showing the losses that actually occur from a failure to have material and stores ready when required. In a shop experience of some years on this Coast, this of all things caused the greatest annoyance. Perhaps some account of this will offer a suggestion.

It was at first a daily if not an hourly occurrence for the tool and store keeper to report: "We are out of half-inch washers; there is no emery cloth; the twelve-inch bastard files are out; there is no waste; certain sizes of tool steel are all used up," and so on. Inquiry and scolding did no good. The thing went on with considerable loss each day, and was clearly a fault of management. The store keeper, who was a very conscientious man, came in one day to report that some stores were wanting. "Go and procure them," was the instruction, "and mark off your time card, now and in future, all the time down to minutes that you spend in going after things in working hours, and as soon as your cards are clear of such charges your wages can be raised, because of the saving effected in the shop." The entries for lost time soon disappeared.

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WORKS ADMINISTRATION.

Lectures before the Students of the Leland Stanford Junior University, Palo Alto, California.

BY J. RICHARDS.

No. 3. October 31st, 1895.

It was foreseen at the beginning that there would be much difficulty in arranging these lectures in sections that would each embrace one subject. This would be desirable on many grounds, but is found impossible, because of the diversity of the topics and the different amount of attention they require.

In the present lecture and supplementary to the last one, will be a short essay on capital, as an element in skilled industry, and then will follow the first of the practical sections, dealing with plant, implements and processes. This second section will relate to what is technically called handling.

THE RELATIONS OF CAPITAL.

It has been shown that under a contract system of skilled work the men do not deal directly with capital, that being the care of owners, but everyone in a works, no matter what their position may be, is interested in capital indirectly, because without this there can be no works, either in organization or implements; besides, the

students here may stand in the relation of owners, managers, draughtsmen, clerks, or workmen, and in all these positions it is desirable if not essential, to have some intelligent views of capital, the same as of material, implements and management, that is, of the relations of capital.

This is especially desirable in this country, where it is common to balance the use of capital against other considerations, making that a permanent element instead of an employed one.

In the first place we will inquire what the term capital implies or includes in a manufacturing business, and here we may say as to the nature of capital, most of the explanations handed down by economists are not very complimentary to their understanding of the subject. In this remark, however, must be omitted Dr. Adam Smith.

Smith, as before mentioned, who in his great work, *An Inquiry Into the Wealth of Nations*, published in 1776, says that "capital is the productive investment in a business; that part which is actively employed to earn profit." These are not the words, but the substance of his definition, and it is quite correct, but as before intimated, there have been long dissertations on the subject, in which men differed, down to the time of Mr. Henry George, who set this matter at rest forever in a single sentence. "Capital," said he, "is what is written in the capital account."

The whole mass of literature on this subject beside, does not afford the light that these few words do. In the abstract, such a simple statement as this would seem trivial, but in the light of what preceded by other economists, the words are a revelation.

People engaged in business have an interest in this problem, and it is necessary to know in the accounts what is capital and what is not. It is common to segregate this element from others and write it in a "Capital Account." This is what Henry George meant, not that the capital account included what was used as capital, which is self evident, but that the things included or listed in this account are such as have been disputed over. As remarked, every business has, or ought to have, a capital account covering investment in buildings, implements, and all the agencies of production owned, but not merchandise, material or wages.

This later statement may appear puzzling to those who have not given previous attention to the subject, because, as all know, it requires a fund to purchase and hold material, also to advance wages for a time, or during the progress of constructing some work, but

neither of these things are capital. In some cases there is no material to provide. The mineral reduction mills at Virginia City, Nevada, and custom mills of this kind elsewhere, are an example. The material is furnished by others, and the mill owners provide only implements, labor and expense. The same is true of custom grinding wheat, and many other operations that will occur to you, where the material is sent in to be treated and returned in kind or in results.

If the owner of a works purchases material he does not pass the purchase to the capital account, but to the merchandise account, which is debited to the amount of the purchase, and credited again when the material enters into work made and sold, so the use of the capital or the material is more in the form of a loan or credit, the real manufacture relating to changes made in the material, such as converting cotton or wool into cloth; or iron, steel or brass into machinery. What the manufacturer employs is the use of the money so invested for the time between the purchase of material and its sale again as a product of the works.

This use of capital, if there has been no change in the price of material, is chargeable with interest for the time, but the investment, or use of capital as we are now terming it, may be a source of profit or of loss by reason of fluctuations in the price of material held. If, for example, a machine-making firm or company purchases iron at fifteen dollars per ton, and during the time of its conversion the price of iron rises to twenty dollars a ton, the gain of five dollars on each ton is not the result of manufacturing, but a profit of trading in merchandise, and conversely, if there is loss by reason of a fall in prices, the loss should go either to loss, or to expense as an element of risk.

These things will be made more plain by noticing the methods of use, or in other words, the organization of a business in respect to capital. In this country the shares or interests in a business are commonly based on capital, that is, the ownership of a business and a division of profits is as the capital provided by the partners in a firm. This is not always the case, but is common, and the usual idea of business ventures in skilled industries in this country. The reasons for this are no doubt the risks involved in such business owing to fluctuations in prices and in other ways, and on that ground may be fair and equitable.

It is easy to perceive that logically considered, and aside from special risk, that is, risk not covered by the rate of interest, capital

is an element that has nothing directly to do with personal interests in a skilled manufacture, and this is very nearly the case in founding an engineering business in England.

The partners or owners are expected to contribute skill, service and connection, and on this the business is founded. If the partners own capital, they can invest it or not. It is hired from the partners, some one else, or from a bank; standing in the same relation as implements, buildings, and so on.

It is easy to perceive the effect of this. Chemists, shoemakers and farmers do not engage in engineering manufactures, as they may and sometimes do in this country. In great firms like Maudsley's, Penn's, Tangyes, composed of many members, there will be no one not a mechanic or engineer.

This is proper and desirable in every way, and will become the rule in this country before long. Circumstances are fast tending in that direction for that class of industry called engineering manufactures.

If the technical education sought in this and other institutions of the kind cannot be balanced against capital or commercial skill, its value is doubtful. It is common for men to say "I can hire all the skill I need," but this is not true of the present, and certainly will not be true of the future.

A man may inherit or purchase an interest in a business already founded, of which he has no technical knowledge, and such business may go on successfully with accession of this kind, but the chances of failure are increased accordingly.

Before leaving what may be called the economic part of the subject, and supplementary to what has been explained in respect to the four components of production, I wish to point out these components; material, labor, expense and profit constitute price, or the amount that is paid for commodities. The price for staple commodities, such as manufactures of iron, wood, leather, and so on, is fixed in the neutral markets of the world, and not controllable in any one country, except so far as taxed to the people of that country, or as a bounty is paid for production. Thus it will be seen that the whole assumes a mathematical form, that of an equation, in which the price equals the four components named.

Now it is obvious that these components can be varied relatively without affecting the equation. The price of labor can be increased

if a like amount is taken from material, expense or profit, or the price of material can be increased if the increment is taken from labor expense or profit, but change the matter as we may, the aggregate must remain the same to balance price.

It is also obvious that no nation or people have the power to control or much alter the price of staple commodities, and whatever enters the world's markets must be sold at the world's price. The country having the cheapest material, labor and expense will successfully export their products, but when I say cheap labor I do not mean low wages.

Fifteen years ago wages in the Geneva watch-making industry were in francs about the same as wages were in dollars at Waltham, but the American labor was the cheapest, and watches made at Waltham were sold all over Europe. In England wages are, and have been for a century past, much higher than on the continent of Europe, but the cost of labor was less in England, so that in a division of these elements or components of skilled production, labor must be considered at its cost, and this has but little to do with a rate of wages.

HANDLING OPERATIONS.

Thus far in these lectures on Works Administration the subjects dealt with have been mainly the conditions that attend on administration, and no doubt less interesting than what we may call practical matters, or the manipulative process of performance. We will now turn to this branch of the subject, and commence with some of the conditions that affect buildings.

General rules that apply to the arrangement of factories and workshops are not many, as may be inferred from the extreme diversity that exists, but such rules as do apply have no attention to speak of, and it would be hard to name any other thing that is so much lacking in uniformity and design as buildings for industrial purposes.

There are certain industries, uniform in nature and old in practice, such as cotton spinning and weaving, that one finds housed and arranged in a tolerably uniform manner, especially in Europe, where cotton mills are sometimes torn down and rebuilt to gain a few feet in width demanded by modern machinery for spinning and weaving, but were it not for this obvious condition of fitting the buildings around the machinery it is doubtful if there would be two mills alike even there.

Grinding grain is an uniform operation the world over, if we except roller and buhr grinding, yet the mills are built in all conceivable forms externally and internally. The causes for this are the absence of rules and information respecting designs, the method of receiving and discharging material, the configuration of ground and its value, and the extension of industries from a small beginning by patching on, as it is called.

With this many reasons, and a good many more not mentioned, diversity is not to be wondered at, but there is at this day some approach to uniform plans for machine fitting shops, that had its origin in England, so far as I know, that of an open central gantry, spanned by overhead traversing cranes, and stages at the sides occupied by machines and fitting conveniences.

Omitting architecture, the strength of buildings and their foundations, the beginning part in planning a works is the handling of material and the completed product, also material during the successive stages of conversion. This is the foundation, so to speak, that must always in a considerable degree affect an expense account and also determine the amount of room required.

Handling is of two kinds, horizontal and vertical, and it will be new no doubt to claim that vertical handling is not only more convenient but much less expensive than horizontal handling. As an example, the ore from deep mines is raised at the rate of two to three thousand feet per minute, and in some exceptional cases at a rate of four thousand feet a minute, or a speed exceeding that of common railway trains. Now we all know that material cannot be moved at this rate horizontally, or at less than three times as much expense if loading and discharging are included, and the same thing applies, but in less degree, in a machine works or factory of any kind.

This fact has become so apparent, in England especially, where room is restricted, that there is but little horizontal moving of machines or material in a works, and the effect of this is much wider than will at first be supposed. For example, whenever material or work has to be moved horizontally on floors, there must be a clear path for such movement, and it is found that in fitting and erecting shops the amount of work produced on a given area can be twice as much as can be done on the same area if the work has to be moved on floors horizontally.

I have in mind now a works in Salford, England, where the erecting floor is nearly impassible, and where there are left only narrow passages for the workmen to get out and in. If a machine is to

be moved it is lifted vertically over the top of whatever lies in the way, moved to its new position and lowered. If a piece is wanted of a weight exceeding what one man can conveniently carry, the crane attendant is signalled, and he does the handling, not only bringing the piece to where it is wanted, but placing while in suspension.

This matter once made a great impression on my mind at the works referred to. I was being shown over the place by one of the owners, with whom I was well acquainted, and when midway on the erecting floor, where we had made our way with much difficulty, he stopped at the end of a planing machine that stood under the gantry and said: "Now I will show you how we handle things here." He signalled the crane man, toward the cleaning room between the shop and foundry, who came instantly overhead for orders. "Bring top carriage, No. 3, Order 400," said he, and in less than two minutes the piece was overhead descending in front of us, and was laid gently on the planing machine bed, a saddle that weighed several hundred pounds. "Hold on," said he, "we will not want it at present, you may return it." and away it went again, sailing through the air, no one noticing or regarding the matter except ourselves and the man on the crane.

The overhead cranes were moving continuously from place to place, picking up and placing pieces from a hundred pounds to thousands. This was at the Gresley Iron Works, at present extended and rearranged, but no doubt just as condensed now as then.

In these works, it may be remarked, were kept the most accurate system of accounts and records that I have ever known in any machine works. The work made is machine tools of a high class, and by a mental estimate made at the time, twenty years ago, and by comparison with the machine-tool works in Philadelphia, the floor space occupied for a given number of men and product was not half as much as in Philadelphia.

The main factor in this was vertical handling, and it is easy to imagine the effect by comparing with a works provided with elevators, but not cranes. The moving of anything on the floors is a difficult matter until an elevator is reached, then all difficulty is ended, except loading on the platform, and this must be included in the horizontal part, because with overhead traversing tackle no loading has to be done.

There is one expedient for handling that is commonly considered crude, but is in fact one of the most important of all, the outside

sling hoist. These are commonly contrasted with an inside hoist or elevator as a makeshift apparatus, but in fact are quite a different thing, and should always when possible be provided, unless a crane gantry can be extended out from the front of a building, and even this is not so convenient or capable of doing the work of an outside sling hoist.

To introduce here another case of experience, and these I am afraid are turning up too frequently in these lectures, I must mention a building erected in San Francisco about twelve years ago, where a sling hoist was placed over the sidewalk. This was against the ordinances of the City, but being in a street not much used the authorities finally consented to the scheme, and a chain was placed five feet away from the building at the front, winding directly on an overhanging drum geared to raise thirty tons.

Opposite the hoist was a tier of wide doors to three stories, through which material and machines could be passed. The hoist was much criticised, people inquiring why a convenient elevator was not erected inside, but the first load raised gave some light on this problem.

Some pattern timber was required, and two thousand feet was hauled to the front of the building on a common wagon. A chain was passed around the load a little to one side of the middle, so it would hang diagonally, and the whole load of timber started for the third story. The lower end was swung around into the lowest front door, and slid up along the front of the building until it passed into the third door, then a roller was placed on the door sill, and on lowering, the whole two thousand feet was landed on the third floor without moving a board from where it had been placed in loading the wagon.

Loads could be picked up twenty feet from the building, or loaded on trucks at the same distance, but this was not the only function of the hoist. When the building was erected heavy curved caps of cast iron were placed over the lower and middle front doors, so a rope or chain could be dragged around these caps without injury, and whenever any heavy machine was to be moved in any part of the floors it was dragged by means of a snatch block and a rope attachment to the outside hoist. We had a complete elevator inside of the building, but it was not thought of for removing material, being employed for passengers only.

Overhead traversing cranes are the ideal method for inside handling in machine works of all kinds. They are elevators with lateral

adjustment, so to speak, reach all portions of a floor, and dispense with a half or more of the laboring work that otherwise must be provided.

There are some fine examples of apparatus in the Union Iron Works, also of radial cranes in the Risdon Iron Works, in San Francisco, and in recent works built in the Eastern States some of the best examples in the world of traversing cranes.

Before leaving this subject of handling as an element of arrangement in works, it will be profitable to analyze the operation in a simple way.

Handling or moving weights consists mainly in opposing and overcoming gravity, a vigilant force acting downward that takes instant advantage of every posssible fault in apparatus. It is the ingenuity of man pitted against Nature. As soon as gravity is overcome, then horizontal movement of a load in so far as resistance has only machine and air friction to contend with, but there is the impediment of shifting the elements of sustension.

If a weight is to be raised in one line, then attachment to any permanent part of a building is sufficient, but if lateral movement is also required, this introduces a new set of conditions, and calls for very different apparatus, a girder or projecting beam must be called in. A radial crane is a projecting beam on a vertical axis, around which the beam and load can be revolved, the service being in circles; but the traversing crane, which is of the girder type, moves in two horizontal planes, and serves a rectangular space, and as workshops are rectangular there is better adaptation.

There is the further difference that the range or area served by a traversing crane is limited only by the length of the span one way, and the length of the ways in the other direction. I do not say "track," not knowing any authority except that of local custom for substituting the old word "way," from German *weg*, by "track," which means properly the imprint of the foot of an animal.

A radial crane is, however, limited by the strains, deflection and other, that permit but a short range, and to serve a floor of any considerable area requires a system of such cranes so placed that the circles swept will intersect, and loads can be transferred from one crane to another. This was the method in this country down to a very recent time, and is now the most common, but is destined to soon disappear because of inconvenience and the lateral strains upon buildings. It is obvious that the top fulcrum of any pillar or swing crane must bear lateral strain as the horizontal and vertical

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components, often equalling the whole load, and if a load is swung the direction of this strain follows the gib, radial from the axis of revolution, pulling the framing and walls of a building in all directions.

In the travelling or traversing type of cranes the strains are vertical, and there is no requirement for the great lateral stability of buildings that raidial or swing cranes demand, a very important matter that may amount to a difference of a quarter or more in the cost of such buildings.

There is no longer any good reason for erecting fixed radial cranes. Their cost, even without provision to support them, is at this day nearly as much as for traversing cranes, and if there is added the expense of provision for lateral support, the radial cranes then cost a good deal more.

A portable derrick crane deriving its stability from its foothold, to so term it, is a different matter, because the function of traversing is added, and the lateral range in one direction is increased indefinitely so that cranes of this kind are the most common of all, and if we include kinds of service such a crane becomes a hybred between the radial and traversing types. Such cranes are not suited for use in a works, because their stability being derived from their foothold they require a wide path on the floor that cannot be spared, hence we see cranes of this kind commonly called into use for all kinds of out-door service.

It will be proper in this connection to say something of the handling faculty, that is, the inception or preception of means and methods.

We have heard a good deal recently of the "inventive faculty," and discussion of the problem whether the ability to invent new things is an intuitive faculty or merely the methodical exercise of skill and experience. I am much inclined to the latter view of the matter, but always in thinking of the thing connect it with the handling faculty. Any one of experience in a works will bear out the proposition that some men seem to know intuitively how to handle and move heavy things and others do not. The best workmen, those skilled in all other matters, are often less capable of handling than a laborer who has this peculiar faculty, and what is more strange, the unsafe men never seem to learn.

In a works at San Francisco, where I had charge some years ago, we had a line of work that severely taxed our handling facilities. We constructed the main part of one machine tool that weighed 119

tons, and made many more of large weight. A portion of the work had to be raised to the fourth floor, and the handling was a source of constant anxiety. The mechanics were called in sometimes to help, and among the rest a young man who operated a planing machine. He was selected because of his deliberate manner and good judgment. He seemed to perceive at once when he glanced at a mass where its center of gravity was, and where to hitch on with the most convenience and safety. The strength of sling chains and ropes, the kind of knots and fastening, the danger of corners cutting through slings and obstructions, all seemed clear to him, and in a week from the first experiment he was put in charge of all the handling, and moved all the heavy weights for years while engaged as a planer.

A main thing in handling by power is to keep men out of the way. Mr. Gilbride, the man I have been speaking of, never wanted but one man to assist him, and often no one at all. He wanted no risks he said, and every man added increased the risk.

It will not be hard to understand this. Each man is in a sense an independent machine, controlled to some extent by his own judgment. His muscular power, except for adjustment, is of no importance whatever in machine handling. The point is to direct the piece of machinery, and the fewer men for this purpose the better. It is true there are a long train of expedients, thousands in number, that must be either invented or learned by observation, many of them simple, and some of them intricate. One I will describe in illustration.

In former times a great deal of timber was sawn in the forests by hand with what are called whip saws, yet employed in Asiatic countries, and sometimes for very long timber in this country. Among other things thus prepared are boat gunwales for floating or flatboats, often eighty to one hundred feet long. The balk or beam from which the gunwales are made is from eighteen to twenty-two inches square. This balk has to be raised about seven feet above the ground, so the pit-sawyer or under man could stand clear and have a sweep above his head, the other sawyer standing on top.

These balks are raised easily by "cribbing," it is called, building up a rectangular pen of short pieces about three feet long, and then rocking and raising one end of the beam at a time. If this crib is three feet square, and the balk is balanced across it, the middle section over the crib will contain only five or six cubic feet, which at fifty pounds to a cubic foot would require but 250 to 300

pounds to tip the beam either way, so that two men by walking on the top to either end would depress it so that a new piece or stick can be inserted at the opposite side of the crib, and thus by tipping the beam first one way and then the other the crib is built up rapidly to the required height, after which a proper truss is put under each end and the crib removed.

I once saw the roof framing of a tunnel raised by a system of compound levers, plain pieces of scantling one behind the other, that exerted a force of not less than twenty tons in a space three by five feet in cross section. Of course a hydraulic jack would have been much more simple and easy to use, but there was no one there except myself who had ever heard of such an implement as this, and perhaps none who had ever seen a lifting screw of any kind. It was not at a mine, but in a water tunnel in the country.

There are a great many different ways of raising and lowering weights, but their fall is on an uniform method, and the difference between a man who can handle successfully and one who cannot is in forseeing what is going to happen.

Prof. Sweet once wrote an essay that gave a new and expressive phrase to the world: "It is always the unexpected that happens." This is a truism in one sense, because a thing to "happen" must be unexpected, but we all know what the Professor meant, and the remark has no doubt saved a great many lives and accidents.

The economic effect of handling apparatus in a shop, such as cranes or running ways over machine tools, small railways in foundries, iron works and factories, is too obvious for comment. Run ways, which is a good name for them, consist of rails overhead for suspension, also on narrow railways on the ground or floor. Both systems are the subject of special manufacture at this day, and the cost of works handling, we may term it, has certainly been diminished by one half in twenty years. There are conveyors for fuel, grain, wheat, ore, and every kind of merchandise, and especially for people, so that, as remarked at the beginning, a foundation or first condition in arranging a works of any kind is to determine the mode of conveyance and handling outside and inside the buildings.

The cheapest method of all for handling and conveying material is by gravity, and the problem of distribution in a works is very often dependent on the elevation at which material can be received. A common quartz mill is an example of this. Such mills are nearly always built on a hillside, so the ore can be received at the top and

descend through the grizzly, bins, breakers, stamps and concentrators, by its gravity, nearly all the handling being dispensed with. The consequence is that in proportion to the amount and weight of material, the power applied, and the number of processes, no other kind of works are operated with so little expense for attendance.

The same thing applies to any works or factory operating on heavy material, and the first care in making plans should be to see if the material and fuel can be received at a height sufficient to permit distribution by gravity. Some kinds of material received in packages, like cotton bales, or barrels, can be rapidly and cheaply picked up, and handled from a train or boat by hoisting tackle, but the average supplies, including fuel, cannot be handled in this manner.

Of course water carriage ends at the ground level, but railway carriage, which is more common, can often be so managed as to deliver at a point high enough for distribution by gravity, and there has of late years been a good deal of attention paid to this matter in the arrangement of plants where there was room for a railway incline.

The Pond Machine Tool Works, at Plainfield, N. J., is a good example. By arranging an inclined way to their works, iron, coal, sand, timber, also supplies that are required on the upper floors, can be handled by gravity, being received twenty feet or more above the ground level.

It requires some room to do this if trains have to be driven by traction, but if hauled up by simple apparatus driven from the works the grade can be ten to fifteen per cent., and not extend beyond the usual yard room required. This, it must be remembered, is not to attain elevation or hoisting alone, but also horizontal movement in one plane at least, because a train or car can be moved to any point along the line for discharge.

There is in England a method of handling by means of a gantry, as it is called, that will not be without suggestion in connection with the present subject. Timber is not in England, or in any other country but this one, so far as I know, sawed to sizes in the forest, but is cut out to dimensions as wanted, partly from logs or balks and partly from deals, the latter being an unit cut in the forest to be re-sawed to order at the trade mills, so that a timber merchant's stock consists of logs and deals instead of a great number of prepared sizes as in this country.

The logs are piled in a yard, over which passes a gantry, an

immense trestle, the legs of which are on trucks running on iron ways. It is a travelling crane with legs to reach down to the ground instead of being supported on walls. This gantry, which may be fifty feet wide, straddles the logs in the yard, picks them up and carries them to the mill, or when received piles them to any height the gantry will admit.

In this way one man, or at most two men, can handle any kind of timber, including the great squared logs of walnut and tulip wood sent from this country, or the still heavier woods from South and Central America. Sawn timber is taken out from the mill and piled up, if that be necessary, which is seldom, because the timber is sawed as it is required for use.

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WORKS ADMINISTRATION.

Lectures before the Students of the Leland Stanford Junior University, Palo Alto, California.

BY J. RICHARDS.

No. 4. November 31st, 1895.

Looking at the subject of handling generally, it is one that always engages the attention of skilled people. Its history forms a most interesting subject, and some problems that will perhaps never be solved. I will call attention to a few facts, first mentioning the vast structures on the Nile, in Egypt, the great stones at Carnac, and the old walls in Central America, involving the handling of great masses by means that are as inconceivable as they are unknown. It is true that some inscriptions and diagrams furnish a clue to the methods, but these involved an element no longer at the control of engineers, that of thousands of men almost without wages.

It may be difficult at first thought to conceive of how the rate of wages should be converted into a dynamic problem, but it is possible, and has a direct application in the general subject now under discussion.

When Dr. Layard discovered the great stone bulls at Ninevah, and undertook to transport them to the British Museum in London, there was no handling tackle available, not even a roller, or timber to make a sled, but there were hundreds of men without wages. There were also hides from slaughtered animals, and the Doctor had made a great cable of rawhide, which he attached to the bulls,

weighing several tons each, and then invited the population to come and drag the bulls to the coast, through the sand, cutting a great furrow such as would be made with a huge plow. This waste of power made no difference, because there were plenty of people with nothing else to do, and the draught of a locomotive represented a mere trifle when paid for in some trifling presents or food.

When travelling on a steamer one time we had among our passengers a gentleman who had recently heard the celebrated lecture of Wendell Phillips on "The Lost Arts." It made a great impression on this man's mind, as it has done on the minds of many people, and he was continually discussing the amazing knowledge possessed by the ancient people of Egypt and India. "Look at the pyramids of Gizeh," said he, "what could man do at this day in raising those vast stones with his puny tackle?"

His enthusiasm was crushed out by a Scotchman who was listening, and said, "What do you know about lifting stones? A countryman of mine, Mr. Rankine, says that all the stones in the great pyramids could be lifted with four hundred and fifty tons of coal, and I believe him far before yourself."

The lost arts need not engage attention here. The present fact is that a man exerting a puny muscular power, costing from one to two dollars a day, is not available for handling heavy weights. Ancient ships with four banks of oars and four hundred rowers, are replaced by steamships, and live only as a tradition.

It was remarked in the last lecture that the arrangement of buildings and what we call plant had to be first considered with reference to handling material, its ingress, egress, and movement while in process.

This is a practical fact that would hardly be reached by inference, but is certainly true of nearly all kinds of business, yet it is hardly amenable to any rules that can be laid down. There are, however, a number of constructive details relating to buildings that may be considered with profit, especially buildings intended for manufactures in wood and iron.

One of these things is the heighth, or number of floors, as we say in speaking of factories. Height is a condition depending mainly on the value of land. Where land is dear the fixed charges for rent or interest on investment being as the area occupied, there is a strong incentive to construct high buildings and numerous floors. This is obvious in all large American cities at this day,

where buildings are towering to a point that mars the appearance of everything in their vicinity, reaching in some cases twelve or more stories.

I have mentioned the price of land as a cause of this, which is correct as an economic proposition, but such construction is enabled by the work of the mechanical engineers, who have rendered high buildings possible by apparatus for hoisting and lowering that almost eliminates height, and has equalized and increased rents to the extent of many millions of dollars each year. This belongs with handling.

It would be an agreeable theme to enter upon the evolution of modern elevators as they are now operated by steam, water, air and electrical apparatus, but these things will no doubt come up in the course of your studies here, which I do not want to trench upon in these lectures, unless in connection with administrative work, such as making plans for and conducting shops and factories. I will, however, say that the practice is marvellous, and if in the older art of railways we had the same control over the motive power that there is in hoisting and lowering, there would be fewer accidents in the streets or elsewhere.

This wonderful improvement in the means of vertical travelling has now nearly reached a culmination. The speed is all that comfort will permit, time is nearly eliminated, and the accidents in proportion to the number of people conveyed are I imagine not one in fifty that occur on railways. The speed in buildings, or for public use, is however confined to about one tenth what has been attained in mines. Whether it will be increased as people feel safe remains to be seen, but the present rate of three to five hundred feet per minute, as before remarked, has given to high stories nearly the same value as those near the ground.

There are, however, many kinds of business that must be conducted on the ground. A foundry should be on the ground, indeed must be in the case of any but for the smaller kinds of work, such as malleable castings. Pits are required for many kinds of moulds, and the heavy weights, the use of water and most of the operations carried on are such as can be performed on the ground only.

The wheel foundry of the Walker Manufacturing Company, at Cleveland, Ohio, is in one sense an exception to this rule. The foundry floor is set on arches that form a sub-story or basement in which is placed the dividing mechanism for operating the gear wheel moulding machines.

A foundry can be in almost any shape not too wide to be spanned with cranes and other overhead tackle. Foundries are frequently dark, or imperfectly lighted, which is a most undesirable feature, because moulds being indented or sunk, and of a color and nature to absorb light, their interior cannot be seen without abundant light or by the aid of artificial lights or mirrors, both of which hinder work and should be unnecessary.

For the last thirty years the trend in foundry practice has been toward a high story, strong walls, of which a third or more are glass, in the lighting plane, which should begin six feet from the floor, and extend to sixteen feet above.

Walls of a foundry require to be strongly buttressed so as to withstand the strains of radial cranes, or bear the weight of traversing cranes, and the roof framing so arranged and tied into the walls as to constitute the whole a connected structure. The roof of a foundry should always be either sloping each way or curved to permit the escape of gases at the top, and fire proof to resist the sparks and coals blown out of cupolas.

A foundry room nearly always takes the form of a parallelogram, with wings for melting, core making, stores and core ovens.

These latter are commonly patched on, and cut off the light on one side, which will answer for buildings less than fifty feet wide and double lighted at the other side. These side rooms, reached by wide arches or doors, form a convenient arrangement for narrow foundries, especially if one or both ends are lighted, but in those of the larger class a lighting space should intervene between the moulding floor and all other rooms, except the melting one.

Machine and fitting shops, unless narrow and not exceeding forty feet in width, cannot be well lighted from the sides unless the windows and ceiling are high, and this is objectionable on many grounds. Top lighting is almost essential in a well arranged fitting shop. As a rule, one square foot of glass overhead is worth six square feet at the sides of a room. The best of all, for shed or single story buildings is what is technically called saw-tooth roofs, extensively employed in England, and well suited for this Coast, but out of the question in any place where heavy snows fall.

These roofs are made on a method that lights the whole interior of a shop in a very perfect manner. The form is much like that of the teeth of a saw, consisting of a glazed angle of about 60 degrees

from horizontal, and a reflecting angle of about 45 degrees, the latter painted white on the inside, facing the glass on the opposite angle, so the light, direct and reflected, is thrown downward toward the opposite lower corner of the room.

Such roofs are employed for weaving sheds in England, and are sometimes called weaving-shed roofs. We should know a good deal more of them on this Coast, and as there are no doubt published examples of the manner of framing and making them, I commend the subject as one worthy of farther investigation by the students here.

Of course a saw-tooth or other top light roof can be employed only for one story, or a ground floor, and as you are aware, this is the rule everywhere for shops where heavy work is carried on.

The subject of floors for machine works is one that must be approached with some caution. If a dozen different skilled men are asked their opinion of this matter the chances are that no two of them would agree. I have never seen but one floor that after being well tried was pronounced satisfactory, and as this was a very exceptional one it may be described.

This floor was in a fitting shop in the works of the H. B. Smith Company, at Mount Holly, New Jersey, near Philadelphia, and was made of cast iron, composed of plates about two feet square, cross corrugated on top, and laid in hydraulic cement. The scheme was suggested by the proprietor, Mr. H. B. Smith, and when proposed was at once pronounced an absurdity, because it would be cold in winter, and the men could not stand on it; but the floor was laid, about two thousand superficial feet of it, and as remarked, was a success.

It was laid in the summer, and the iron being a good conductor, the lower temperature of the earth beneath the floor produced a temperature several degrees lower than adjoining rooms having wooden floors. When winter came there was a surprise. The iron floored shop was several degrees warmer than the rest, because of the transmitted temperature from the earth.

These facts of temperature were not, however, the only new feature of the metal floor. It was carefully laid and level. The top soon became smooth, and being greasy, as all machine-shop floors are, the work in the shop could be slid about the same as if on ice, and handling became an easy matter. A machine weighing five hundred pounds could be slid about by one man, and except as to the

workmen slipping sometimes, this sliding feature proved to be one of much convenience.

This floor has been in use since 1876, and I have not heard of any fault being found with it since, also suspect the method was farther applied in the works of that Company.

On the whole it is safest to say that a floor covered with wood, such as pitch pine at the East, and with good Oregon fir here, is the best, but if not treated or saturated with some preservative compound will soon decay.

I say covered, because all machine shop floors should be covered with a wearing surface of blocks or planks, the latter in pieces of uniform dimensions, so that worn spots can be renewed by patches. Such floors, as remarked, are perishable when made of fir such as we have on this Coast, unless the timber is saturated with tar or other preserving compound, or are ventilated beneath, which latter is seldom possible.

Floors of brick, or wooden blocks set on end, of bitumen, concrete, or broken stone, are met with; their merit or endurance depending generally on the thickness and the care with which they are made. As remarked, none of them are satisfactory, for the reason that they are destroyed in use no matter how well made. No substance can long withstand the handling of heavy castings and machines, the use of crowbars and exposure to oil, water, and the continual abrasion of rough use.

Thickness was mentioned, and for masonry or other composite floors this is the main thing. The streets in London and Paris furnish a lesson in floor making. A street there consists of two elements, the street proper, from one to two feet in thickness, a rigid impervious arch of grouted work or masonry, and a renewable cover on top made of bitumen, wood, or other substance. The street, that is the substructure, is not subjected to wear, but remains for ages when properly made, and the covering is varied to suit the grades and weight of the traffic. In London, the hilly portions, or where there are slopes, the streets are covered with wood, set on end; for the heaviest traffic the covering is of granite, and in other cases of asphaltum. In Paris, the covering is mainly of asphaltum, now made into blocks, laid on broken stone filled with mortar or cement, the thickness of the latter being from 11 to 22 inches.

In this country, I am sorry to say, the substructure is commonly omitted altogether, with a result that need not be described. In Chicago the custom was formerly to level the sand, put on a cover-

ing of boards one inch thick, and then on top a course of wooden blocks. This did well for a short time, and then ended.

I am speaking of streets, because the ground floors of works present almost the same problem as shop floors, and as we have not in two thousand years made much progress in street making, rather the reverse, as Professor Marx can tell you, so it is not to be wondered at that one gets into difficulty in recommending methods of making ground floors in works.

As to the economy or cost of producing work on ground and upper floors, I am of the opinion that for the lighter or a mixed class of work, and where one floor is on the ground, upper floors are as good if not better than those on the ground, when there are proper facilities for handling.

At the works of J. A. Fay & Co., at Cincinnati, Ohio, where I was once connected, the work was carried on in a building of four stories. The work done was of miscellaneous kind, principally wood-working machines and their accessories.

There was an excellent opportunity for determining the effect of the stories, because the work was frequently shifted from one story to another, and was nearly all made by the piece. Records and facts there went to prove that the highest floors were best. The light was better and there was less to observe through doors and windows; less visiting and running about. The piece workmen on certain jobs preferred the fourth floor. For handling there was what has been called an outside sling hoist, an elevator for passengers inside, and speaking tubes to the office and other departments from all the upper floors. These works have been much extended, but so far as I know the four stories have been adopted for all working departments.

Upper floors in works and factories are supported on two different methods in this country, called beam and joist floors. Beam floors are common in New England, and joist floors in the Western country, including this Coast.

A beam floor is one where a thick covering, usually double, is laid directly on beams placed from four to six feet apart. Joist floors, commonly single, are tongue and grooved, and laid on joist from twelve to eighteen inches apart.

The beam floors are strong in respect to sustaining static strains, or heavy weights, and weak in so far as vertical rigidity. It is sometimes said you cannot fall through such a floor, but think you will when walking over one.

Joist floors are much more rigid and capable of withstanding jar and vibration, and, as I believe, are preferable in many ways. Analyzed, such a floor is simply one with the beams divided vertically into several parts and spread along the floor at closer intervals, but it is commonly estimated that such floors occupy a double space vertically, that is, are twice as thick, and demand a higher building for the same head room in the stories. This is true as such floors are commonly constructed with the joist resting on the top of the girder beams, but this is not necessary, because the joist can be framed into girders without weakening the bottom chord, so the girders and joist will be flush on top and nearly so on the bottom, and so the whole floor will be no deeper than one made on beams. The Tool Company building, on Stevenson Street, in San Francisco, is an example of this kind of joist-floor work, and I may mention that it met with unqualified condemnation from the architect, but it has never yielded so far as I know. The floors have withstood severe use for twelve years past.

The roofs, walls, windows, and other elements of industrial buildings not subjected to wear and disturbances by the processes carried on inside, except as to cranes and overhead tackle, can be left to the architect, who at this day is fast becoming an engineer as well as an architect; indeed, our modern buildings, constructed of iron and steel, present in all respects affecting their stability, what are clearly engineering problems.

In what has been presented in a fragmentary manner, of handling apparatus, lighting, and floors, there may be no doubt useful suggestions that may at some future time aid in conclusions when you have buildings or shops to erect, and while touched upon only here and there, even one little point may well repay the time you have spent in hearing these remarks.

Every one in charge of works, as an owner or manager, will find more or less to do in dealing with buildings, in their extension or repair, if not in erecting new ones. It is a necessary and inevitable part of administration, a perplexing part sometimes, and one in which the principal aid will be drawn from observing, asking questions, and listening to suggestions such as have been here given.

This far in these lectures we have gone over the objects of skilled industry; the elements of production, material, labor, expense and

profit; the handling of material, and some notes on buildings. The next subject will be the equipment of works, beginning with motive power.

On this subject the nature and types of motive apparatus operating by steam, air, gas and water, will form a part of the regular studies here, and the only points that fall within the province of these lectures will be a choice of motive apparatus; its disposition in plants and distribution, so far as affecting arrangement and results.

There never was a time in the history of mechanic arts, since motive power was a prominent element therein, that the matter of determining the kind of power to employ has been so much a problem as it is now.

This fact was brought to mind in a forcible way a short time ago, when a friend who has a fruit farm near San Diego, in this State, called to inquire what would be the best means of raising a certain amount of water required for irrigation on his farm? The water, not exceeding three miner's inches, or about thirty gallons a minute, had to be raised two hundred feet out of a cañon to the top of a hill where a reservoir was to be constructed.

The choice of motive power laid between horse power, steam engine, a gas engine, or wind wheel, either of which would do the work, amounting to from one to three horse power according to the time of operation, whether continuous or at intervals.

With horses there was to be considered their original cost, feed, maintenance, and other useful work they could perform on the land.

With steam there was the question of fuel, danger, skilled attendance, first cost and maintenance.

With gas or oil there was to be considered cost and weight of fuel, attendance, first cost, risk, and some doubt of ultimate efficiency under the management of unskilled people.

With the wind wheel there was the first cost, maintenance, amount and constancy of wind, the periods of wind in relation to the period of irrigation; but most of all, position. The water being in a cañon and the wind on the hill top, there was no means of connection with the ordinary apparatus.

These four methods were put into an equation, so to speak, and no conclusion has yet been arrived at, because some of the data, such as the period of winds, was not determinable at the time.

Now if this simple proposition, involving two or three horse power, includes, as you will see, a large number of technical con-

ditions, more perhaps than if there were three hundred instead of three horse power to deal with. There is much risk of not recommending the best apparatus, and a positive certainty of almost every one else claiming that the selection was wrong, no matter what it might be.

Bearing upon this case, and others of the kind, which include the most of all the small irrigating plants on this Coast, is a recent discovery or method that deserves some mention here. It relates to a means of communicating power from a wind wheel or other motive machine to pumping apparatus placed at the source of the water supply, or within suction distance of twenty-five feet or less.

In this new system there is a pneumatic expulsion device or pump placed in the well or spring, connected with an air-compressing pump at the motive apparatus, so the latter can be set on a hill or in any other convenient place. The flow of water in uptake pipes is from three to five feet per second, while the flow of air under like pressure would be about one hundred times as fast, so that a very small pipe will convey the power from the motor to the pump. The advantages of such an arrangement are obvious, but I am unable at this time to give any data respecting efficiency.

In preparing or organizing plants of any kind there are always present some or all of the conditions named, generally a good many more, all connected or corelated, some of them variable and some of them not ascertainable. Such problems arise continually in the administration of an engineering or machine works; indeed it would not be far wrong for this Coast to say that a third of all the cases where power is required in the country or in the mountains, most of the conditions named come up for consideration. They are not, however, present in most schemes for founding a factory or works in cities or towns, except as to a choice between steam and gas or oil engines, but the distribution of power beyond the prime mover is always a problem forming a part of preliminary plans and admitting of widely differing methods.

As before remarked, there are various means of transmission, including shafts, bands, ropes, wheels, motion rods, water, steam and electricity, but the problem in such a case is not one of choice between these methods, but a division between them. A visit to any large works at this day, the Union Iron Works, at San Francisco, for example, will show that nearly all these methods are necessary or expedient, and that steam, water, air, electricity, shafts and ropes are all in use for conveying power, not exceptionally with any one method, but extensively with each.

There is at this time an increasing amount of transmission by electrical apparatus. It is new, and its future adaptation not yet known, but there is little doubt of its wide and extensive use for rotative motion, not, however, for rectilinear movement, for which there is at present no adaptation, except for such short movements as may be called adjustment.

At the Union Iron Works, that have been mentioned, ships and other heavy loads are raised, and many machine tools, such as shears, presses, and the like, are operated by hydraulic apparatus. Power is distributed by long ropes and shafts, but there are present plans of a wide use of electrical apparatus that will supplant the ropes in nearly all cases, and the shafts and steam in some cases.

Coming now to particular things, one of the first, and always a matter of some doubt, is first movers or main transmission, now-a-days performed with bands, ropes and tooth wheels. In so far as endurance and results the methods of a century ago have not been much improved; that is, tooth gearing, then extensively employed for first movers, remains the most perfect at this time, with the least loss in friction and the freest from detention by accidents, but as we are told in respect to the conduit system for electrical railways, tooth gearing is "commercially impossible," because of first cost and the skill required in making wheels that are noiseless, safe and durable.

The cotton mills in England, many of them, are thus geared, so also are rolling mills there and in this country, but for factories bands and ropes are all that need be considered. In the case of large powers and where detention would be serious, as in the case of driving the machinery at the Centennial Exhibition of 1876, from one central engine, Mr. Corliss fell back on the practice of Boulton & Watt, and employed beam engines and tooth wheels.

Sir William Fairbairn never could become reconciled to what he called "wrapping connections," that is, flexible bands and ropes. He looked upon them as cheap expedients, not transmitting positively, and liable to fail at any moment. You will not find warrant for this statement in his writings perhaps, and it may interest you to know that I am quoting in substance remarks made to myself in 1869.

Sir William, the noted Manchester millwright, and an authority yet in many important matters, had then a works at Manchester, and was at the time making some huge iron casemates or forts to be set up on the coast. I had a letter of introduction to him, and, as people often do, made the mistake of presenting it in person, thus

dictating the time of his attention to myself. After waiting a time he sent for me, and when he began to rise from his chair I wondered when he would stop, He was a very tall, brawny man, angular and impressive. He gave me his hand, or rather took mine, with a grip that hurt and astonished me. In a long and interesting talk that followed he expressed his views as before noted, but spent most of the time in asking questions about this country.

If the element of cost is eliminated it would be very difficult indeed to show wherein our modern methods for first transmission are better than the old one of tooth wheels, but cost is a very important matter in this case. The difference does not lie so much between tooth wheels and "wrapping connection" as it does between the foundations and supports, which are the most expensive part.

A main part of the duties of an engineer or mechanic at this day is to harmonize and corelate the two elements of cost and quality. This matter is illustrated by a remark once heard in a club discussion in London between some English and Ameaican engineers on the subject of American railways. One of the speakers said: "It requires no great engineering skill to make a short railway with a large amount of money, but to build a long railway with very little money is a very different matter."

In this country, and in all others where the interest on capital is high, and where changes are so rapid as to cause indifference to permanence, it would not be good practice to adopt tooth gearing for first movers in any but special cases. There are, and always will be, circumstances where such gearing is expedient, as when heavy power is transmitted at a right angle, or when positive motion is necessary. Bands and ropes answer very well, and have the great advantage of operating at various distances, a feature that in itself is of such importance as to determine method in most cases.

LINE SHAFTS.

Referring next to line shafts for distributing power. It is an object in the case of long shafts to apply the power at the middle, so as to divide the torsional strain each way, and this is usually easy to do in laying down plans for a plant, but when shafts do not exceed 200 feet in length there is no objection to driving from one end, and except the first or main section such shafts should be of uniform diameter. A common impression, and error too, is in reducing the diameter of line shafts in proportion as their work diminishes from the driving end. This is done in most cases without knowing or

considering the difficulties that result from this method, and also from a mistaken conception of the difference in cost between uniform and tapered shafts.

It is natural to suppose that the price of a shaft is as its diameter or capacity, but this is not the case. The most expensive elements in line shafting are the couplings and bearings, and as these increase in number for a given length of shafting approximately inverse as its diameter, the difference between a shaft two inches in diameter and one three inches in diameter is nearly as the difference in weight of the material, and as the value of the material is only a third or so of the finished cost of a shaft, it will be easy to see that the price of a shaft does not follow as the diameter.

The cost of couplings, either of the rigid or compression kind, is about five dollars for each inch of diameter of the shafts to which they are applied, and the distance between couplings and bearings is commonly about fifty diameters of the shafts, so that as between a shaft of two inches diameter and one of three inches diameter the fittings will be in number as two to three, and the weight or cost approximately the same. The shafts themselves will cost as their weight, or as the square of their diameter.

Then again, the torsional and deflective strength of shafts increases as the cube of their diameters, so you can see that selecting or determining this matter of line shafts is not by any means an easy problem, and is especially so if we set out on the basis of the power to be transmitted.

In Sweden where mathematical methods are too much followed in some things, I was told by a young engineer that he had been set at work to find out the proper diameter for a shaft, and after he had by careful computations, respecting torsion, deflection, and so on, arrived at the proper size, the manager told him to quadruple the dimensions for safety, in other words, assume four as a factor of safety, which was not too much, but it seemed to the draughtsman inconsistent.

This matter of selecting and arranging line shafts for distribution in works offers opportunity for a short digression here, and some remarks on proportions that I think will not differ from, or at least not controvert, what Prof. Smith has taught or will teach in respect to factors of safety.

Rules in this respect apply to the strains in all kinds of static structures and works of all kinds so long as things "stand still," or when they are in motion under normal conditions, but in machinery

the proportions must arise out of accidental strains, which unfortunately lie outside the field of computation. For example, a line shaft should be strong enough transversely to tear in two the double of any band leading to it.

Now this is not a proper function of a line shaft, but bands will get "wound," as it is called, and unless a shaft will tear them in two the band will tear the shaft down, or bend it, which is nearly as bad, unless we include the effect on what is beneath the shaft when it falls. I once saw a line of more than 100 feet in length lying on the floor or on top of machines and material it had fallen on, but the fault in this case was bad attachments by means of lag screws, which are safe when properly put in, but always suspicious, because there is no visible proof of their integrity.

All this is, however, not bringing us any nearer to the proportions of line shafts, at least to any definite rule, but suggests one of a vague kind, namely, to carefully search out the accidental strains and provide for these, always erring on the side of excess in proportions.

The best clue to dimensions is found in deflective strains, considered in respect to bands, tooth gearing and the chances of obstruction from any cause, but these strains are irrespective of speed, consequently are not measurable by horse power transmitted, so we are only getting deeper in the mire as we go on, and to get out of the difficulty I will refer to some of the well-known formulæ, such as the diameter of the shaft in inches should equal the cube of sixty-five times the horse power, divided by the number of revolutions per minute, written:

$$D = \sqrt[3]{\frac{65\ H.\ P.}{N}}$$

and the distance between bearings should be in feet five times the cube of the square of the shaft's diameter in inches, written thus, L being the distance in feet between bearings:

$$L = 5\sqrt[3]{D^2}$$

Now if these rules are analyzed it will be found that the proportions derived have no reference to computed strains, but to accidental strains.

The coefficient 5 in the second formula should, I think, be 4 to 4.5 when the belts are led off between the bearings.

WORKS ADMINISTRATION.

Lectures before the Students of the Leland Stanford Junior University, Palo Alto, California.

BY J. RICHARDS.

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Continuing the subject of line shafts as an element in laying out and arranging works or factories, it may be well to analyze to some extent their nature and construction.

John G. Bodmer, in 1848, in a limited way and Wm. Sellers & Co., of Philadelphia, as early as 1860, perhaps 1855, in a complete way, introduced pivoted bearings, and explained their purpose and importance, but thirty-five years has been required to attain a general use of such bearings for line shafts in this country and has done little more than begin their introduction in Europe.

No line shaft runs precisely true, and very few run reasonably true, so that rigid bearings to support such shafts are unsuited, and cannot fit the shafts except at one point, consequently we had the old rule of making such bearings one and three quarters the diameter of the shafts in length. In Europe nearly all line shafts are so mounted, commonly on brass, so the shafts will not be destroyed by the abrasion that is sure to take place when a flexible shaft is mounted in rigid bearings.

To convince any one of the importance of pivoted or movable bearings, it is only necessary to have them feel such bearings, when even the truest shafts are in motion they are never still. The difference between contact and non-contact in bearings is within thousandths of an inch, even if allowance is made for a film of oil, so it is easy to see that a rigid bearing will not be worn parallel, and that adding to its length will only increase the difficulty; hence, as before pointed out, such bearings must be short and of some soft metal or alloy that will not abrade the shafts.

Messrs. William Sellers & Co. when they pivoted line-shaft bearings, increased the length to four diameters, and made them of cast iron, which, under the lighter pressure due to added bearing surface, is an excellent material for such bearings. Messrs. Sellers & Co.'s improvements did not stop here. They made the bearings adjustable vertically, and connected the shafts with clamp or compression couplings, so the parts became interchangeable, and this reduced the making of line shafts to a manufacture instead of special work.

It is not very easy to realize the effect produced by interchangeable couplings. A shaft fitted up with rigid keyed-on couplings is special machinery, because each coupling has its mate, and each piece of shaft must go to a particular place. A shaft to be extended must be taken down and another piece matched to fit it. The couplings change everything.

It is sometimes claimed that compression or interchangeable couplings cannot be made strong enough. This is a mistake. I do not say they are made strong enough when fitted with conical bushes, tapering screws, and such contrivances, but when made as an embracing clamp and bolted on, they are quite as strong as the shafts they connect. When a shaft breaks down at sea they do not use conical bushes, which have no adjustment, taper screws, wedges and so on. They place clamps around the shaft with flanges for bolts, screw up the clamps and go on.

I once saw some experiments with interchangeable couplings at Manchester, England. Examples were procured of the different kinds made there and in this country, and two steel shafts were mounted so as to be forced out of line at the coupled joint. After the couplings were put on, the shafts were set in motion, and forced out of line until the couplings gave way. Nothing withstood these tests except plain clamp couplings, which broke the shafts, and there is reason to believe that after scores of ingenious inventions no other method of connecting shafts is so good as the very oldest — a plain embracing clamp bolted on.

In laying out a factory or shop in which line shafting and machines are to be erected there should be a base line made on the floor, preferably in the center, parallel to the line shafting. This score should be made deep enough to remain for years. A good plan of making it is to first strike a chalk line on the floor, then lay a straight edge along this line as a guide, and score the floor with a hook tool, such as wagon makers use in marking out their stuff. Another way is to drive pieces of brass or copper wire along this line at intervals of one or two feet, so these can be found at any time, but a score is preferable.

This should be the first thing done when a building is completed, or even before it is completed, parallel with the main walls. The uses and importance of a base line of this kind are so obvious that no one who has ever had occasion to refer to one will forget or neglect such a provision where they have millwright work to do.

The first use of such a line is generally to set an engine or other motive power at a right angle thereto, and thus insure a correct relation to the building. In erecting shafts in any part of the building parallels can be made from the base line, and marked either on the floor or the ceiling, but one of the greatest conveniences of all is in setting detached machines in any part of a room. They can always be set with definite relation to the building, the line shaft and the motive power.

I adopted this method in erecting a woolen factory many years ago, and have no doubt scores of other people have done the same thing. In that mill, the owner informed me twenty years later that the old base line had saved him hundreds of dollars, and was constantly referred to when any machinery was changed or added.

This you will perceive is proceeding in precisely the same way that trigonometrical work is done in surveys. A base line is first laid down from astronomical observations or fixed monuments, and then all map work and surveys are made from this base line.

THE SELECTION OF IMPLEMENTS.

In the equipment of works and factories, and their administration, must be included the selection of implements, and this is commonly a matter of much difficulty, especially if one has nothing to guide except the fulsome literature of the makers.

While there are no rules that will be of much value, there are a good many circumstances that should qualify selection, and to these some space can be devoted with advantage. As machines and pro-

cesses become special, now the tendency in nearly all branches of constructive work, the difficulty of selection becomes greater, and such selection a measure of the administrative ability of an owner or manager.

The first thing that a skilled person observes on entering a works is to note the adaptation of the implements to their several purposes, and from such adaptation is made up a mental estimate of the skill exercised in administration or selection. Few people suspect how much this thing becomes an exponent of capacity. An implement of any kind used out of place, an expensive machine not required, or a special one that has no discernable object, is at once set down as a result of ignorance, sometimes unfairly, but the impression is just the same.

In selecting implements there are a number of things to be considered besides their efficiency and cost. There is, for example, second-hand value, a thing not often thought of.

Most machine tools for metal and wood have a period of life in respect to efficiency, or relative efficiency. This life depending on improvements is not long, if an average is taken, certainly not exceeding ten years in this country. A machine may not be replaced at the end of this time, but that does not matter; it is in a sense extinct when an improved one will earn its value in one or two years, but this does not relegate the old machine to the scrap heap. It may have a useful place in another service.

The second-hand value of a machine depends commonly upon whether it is a standard or special one; that is, whether it be for general use in a class, or for a particular work. These names, "standard" and "special," which will be frequently employed, have this meaning in a technical way, and are very convenient terms, though not strictly relevant.

There are strong reasons when a choice can be made, for adopting in all cases as far as possible standard machines of good quality, not only because of the second-hand value of such machines when they are superseded by improvements, but in case of failure in a business.

It may seem a strange part of Works Administration to provide for failures, but it is a thing not to be neglected. The statistics of manufactures in this country will show an apalling proportion of failures, and a manager who does not keep this in mind neglects a thing that should be well considered.

I will illustrate what is meant by two cases that have happened

in San Francisco within a few years past. No other method will so clearly explain this matter of second-hand value, and what it may have to do with administration.

In the first case it was conceived by some experienced people who had carefully considered the matter, that milled or finished machine screws could be made at a profit in that city. The margin of profit was small. That was known because of the complete organization of this manufacture in the Eastern States, and it was known that sales competition would be great, but that the making of special screws to order, and a partiality for home-made work, also the avoidance of a large stock that merchants had to keep on hand, and the cost of carriage from the East, it was thought would form a basis for a successful manufacture. The scheme was a good one for the circumstances that existed then, and the business was commenced.

When it came to procuring implements, the foreman, who was skilled in this manufacture, said he could make the required machines cheaper and better than could be procured from the regular makers of such machines at the East. This was done, and here was made a serious mistake.

The machines were made without finish and in such a manner as could have been expected. They would perform the work, but were imperfect in various ways, and confined to special kinds of work. The work went on, however, successfully for a short time, and then came a change. Previous to that time, in the Eastern factories each workman had operated one screw machine, milling, threading, and cutting off the screws, performing various adjustments and measurements by hand, but some one in the Eastern States began making automatic screw machines, several of which could be attended by one person, and the operations being automatic or self acting were more exact as well as more rapid.

All at once the discounts on the machine screw lists were increased to such an extent that screws could not be made on the San Francisco machines without loss, and the business had to end.

Now any one acquainted with the implements employed in screw making knows that most of them are standard rather than special machines, capable of doing a good many different kinds of work in a machine shop, consequently having a definite market value aside from screw manufacture, but no one wanted the special machines provided in this case, and the whole outfit, nearly new, had to be sold for less than a quarter of what it cost, and was a bad bargain at

that price. The outfit was pratically lost, but had it consisted of standard machines, by reputable makers, the whole could have been sold for nearly the original cost, and a good share of the investment saved.

The second case will not detain us so long, it relates to the manufacture of a certain kind of window fittings, that was founded on a local invention. The skilled manager did not, although the processes were mainly of a special nature, set out to devise machines, but selected standard ones from good makers, adapted as nearly as possible to the purpose.

The business failed, for certain reasons that will be discussed in a future lecture, but the investment in implements, which was the main part, caused but little loss because all the machines were sold at nearly the original cost.

It is an ambition, laudable in one sense, but a mistake economically, to attempt making special machines when those of a standard kind will answer. It is a common thing for mechanics to imagine they can design and make all kinds of machine tools and implements better than those in common use, even for regular purposes, but it is a mistake, and may result as in the machine tools for screw-making, made at San Francisco.

Millions of dollars have been sacrificed on this conceit, lost by honest effort but mistaken premises, and by a neglect of second-hand value. Sometimes it succeeds and succeeds well, but more often a shop filled with special implements of some one's devising "comes to grief," as we say, especially on this Coast, where the changes and diversity of work and processes are such that it is dangerous to go far in the direction of special machines, however ingeniously they may be contrived.

This is very conservative advice that I would not have given twenty years ago, at least did not view the matter then as I do now. The propositions are from observation and experience, not from inference, and the stumbling block pointed out is one that most people with experience have at some time stumbled over.

It will be fair to point out in this connection, as most of you well know, that a great share, or even the greater share of our regular manufactures have been founded and succeeded by the use of special machines. It is indeed the key to success in this country where emulation in skilled industry rests to a great extent upon special machines and processes, but in a machine works or an engineering establishment doing a miscellaneous line of work the circumstances

are wholly different, and as you will find, are substantially as have been pointed out.

COMBINATION IN MACHINES.

Next we will consider combined machines, or combination machines as they are commonly called, and in this branch of the subject we need not be confined to machine shops, because the conditions apply throughout industries of all kinds where machines are employed.

A combination machine is one having two or more functions, or is capable of performing more than one operation, and I have sometimes thought is of all the ideas or elements that enter into machine construction, the one most likely to lead to mistaken design, and is the farthest from logical determination; one that causes great and serious losses, especially in the rapid change to organized manufacture that has taken place in the last twenty-five years.

As in previous cases, I will attempt to make this matter more clear by an illustration.

In 1865, thirty years ago, when machine combination was much less understood than it is now, and when there were more reasons for combined machines. I was called in to examine a new machine for making carriage wheels. It was a very ingenious one with a great variety of well-made details that would set and drive the spokes of a wheel, cut them to length and make the tenons, plane, true up and bore the fellies, press the wheel together and then turn it true on the sides and circumference.

All these operations were performed in a very perfect manner by the sanguine inventor, who had sent his machine some hundreds of miles to a large manufactory of carriage parts in Columbus, Ohio, where the same industry is very extensively carried on at this time.

One of the owners, who was a thoughtful and observing man, witnessed the performance of the machine, and at the end went to the office, where he was followed by the inventor, who expected to receive an order from the firm. The owner said:

"Your machine is ingenious, well made, and performs its work admirably, but we cannot use it profitably. If we were to adopt the method you would have to furnish us not less than fifteen machines to begin with, so the various operations would each be continuous and permit organized work, but if you will separate your machine into six parts, each to perform one operation, I will consider the matter of introducing it here in our works."

Both the inventor and myself learned a lesson there, not forgotten on my part, and no doubt well remembered by him. He had been laboriously and expensively at work in a direction just opposite to the requirements, and had mistaken the ingenuity of combination for efficiency. His premises had been drawn from a small shop where a single man instead of fifty, performed the machine work on carriage wheels, and had saved nothing but some machine framing and at the same time hampered and spoiled each function of the machine by interdependence and interference.

Instead of this illustration of machine combination, I could have employed here one of greater importance, that relates to a massive metal working machine, or machine tool, made in San Francisco at a cost of more than twenty thousand dollars, that after doing duty for some years, one thing at a time, had to do as Mr. Carlyle said of the publication of *Sartor Resartus*, "take itself to pieces," and perform its functions separately. Examples are not wanting. They are on all sides; less common now than formerly, but to be seen in some degree in almost every shop in the country.

For a kind of analysis of this combination idea or system in implements, we may consider just what is gained, and this will come down to but little more than the supporting frame on which the working parts are mounted. If, for example, a machine is made for planing, sawing and boring wood, or for milling, drilling and boring metal, the operating elements for each of these operations must be provided much the same as for three separate machines in each case.

The same spindles and driving band may answer, but the saving thus effected will be many times lost by a strained and incomplete adaptation, cramping and interference, so that, as remarked, the main supporting frames are about all that is saved; but, supposing that three fourths the cost of these machines were saved by combination, what would that weigh against the fact that only one operation could be performed at a time, and that the machine was so constituted that only one man at a time could use it? The floor space occupied would be less than for three machines, but no less in proportion to product and workmen, so that in the end nothing is gained, but a great deal is lost.

The division of labor and of processes has in this country, under our factory system, very nearly destroyed the combination idea in so far as machines, and even in hand implements it is disappearing for organized use, now and then one meets with these wonderful com-

bined implements. One of the last I have seen was a machinist's hand apparatus, it might be called, consisting of square, bevel and surface gauge, measuring scale, depth gauge, and so on, all in one implement, convertible by attaching, removing and changing parts. That a practical man would bother himself with such a thing no one can believe, and even the possession of such a contrivance would stamp a workman as either inexperienced or inefficient.

Notwithstanding all these impediments and objections, there is a place for combination implements and machines, but it is not a large place, and is not in a regular shop or works. At sea, for example, it is proper to have a lathe arranged for turning, drilling, boring and milling. Room is an object, and as these operations are seldom performed, and only one at a time, a combination lathe is expedient. Also in amateur operations, in small repair shops, and perhaps in all cases where one man does all the work, combined machines may be profitably employed. Perhaps this last qualification of one man, furnishes a constant rule in the case, or is at least as near a rule as any condition that can be named.

Space and weight may also be reasons for combined hand implements. Any one using a bicycle, for example, cannot carry with them anything having bulk or weight. A combined wrench, screwdriver and hammer is a proper implement, but not for the men who made the same bicycle in a factory.

Segregation is the rule at this day, and one who separates a machine does a good deal more than one who combines two or more machines. The more separation the better, so long as each element can be kept continuously at work.

The practical application of these propositions, as you will perceive, belongs in the administration of a works. Few people are so wise as not to be entrapped by the idea of "two machines in one," or two machines for one price. It is indeed a most practical problem in arranging a works and providing implements, and I fear is one much neglected in books, lectures and lessons treating upon machine construction.

ORNAMENT IN ENGINEERING WORK.

The subject of ornate display in machine construction may well have some place in these lectures. It was formerly a conspicuous element in all kinds of structures, both where it properly belonged and where it did not, also has been a theme for discussion since the time of James Watt, perhaps much longer.

There is on record an anecdote of James Watt in this connection that will bear relating. At the Soho Foundry, after James Murdock became a manager there, about the beginning of this century, he was entrusted with the design and construction of some large blowing engines for melting or perhaps smelting iron at these works.

The engines, three in number, were erected in a basement with a steam engine to drive them, and from some recent drawings of this work, which has been pulled down during the present year, the plant was a very complete one, and much like one would be made at this day.

Murdock was much pleased at his achievement, and had it completed before Watt saw it, he having been away from home no doubt. Mr. Murdock managed to keep Watt out of the room until the work was painted in fine style. The columns, of which there were a large number to support the air cylinders, were painted in imitation of marble, and other ornaments of like nature were applied. When Watt saw the work he looked it over carefully, and approved of it, but as soon as he had inspected it, he astounded Murdock by sending for a painter to give the whole plant a coat of slate-colored paint.

Whether Watt originated the idea of painting cast-iron work slate color or not I do not know, but certainly it is a very good one if that includes the steel color that has now become a kind of exponent of good work.

This subject of paint for machine frames is a matter of some importance and well worth attention. One of the objects in view is to attain a harmonious color, one that comports with the material, and that I need hardly say is the color that looks most like material to which the paint is applied.

Common custom has assigned to cast iron what is called a steel-blue, and this color has become conventional, because the pigment is a permanent one when of good quality, and for some reason, unexplainable perhaps, brings into strong relief any finished surfaces about a machine. This latter is rather a curious matter. If a machine is painted white, blue, green or red, the finished surfaces seem to be absorbed, and do not "stand out," as it is called, but this is not a result of tint so much as the absorption of light, and this depends on the absence of luster.

Machine paint should not reflect light. If there is reflection then not only are the finished surfaces obscured or drowned, but every little imperfection in the casting stands out in magnified relief,

while if the surfaces are dead or lusterless they look smooth and imperfections do not appear. This luster in machine paint prevents successful photographing to such an extent that at one time Messrs. William Sellers & Co., of Philadelphia, lime washed their machines to attain an opaque surface, and then after photographing them washed off the lime coat and applied the permanent paint, which was of the regulation color, but could not at that time be procured without luster.

This circumstance caused the paint makers at Philadelphia to enter upon experiments for producing a machine paint without luster that would retain its tint and resist the action of animal oils, the latter a very difficult thing to do, also possessing the quality of extreme hardness.

Mr. Tully, of that city, succeeded in producing such a paint, which soon came into use there and elsewhere, until the manufacture became a very extensive one, and is yet carried on by Messrs. Raw & Sibley, of that City. This paint requires no preparation, except thinning, it is called, with spirits of turpentine, and can be applied without skill. The surfaces are dead or opaque, and perfect photographs can be made of machines so painted.

As remarked, these dead colors to imitate as nearly as possible the blue tint of scaled cast iron have become conventional all over the world, or at least over that part of it where the subject has had attention, and people have been educated in what may well be called a matter of logical taste.

The chromatic style of machine painting is now confined mainly to machines made in part or mainly of wood, and such as are for household use, but there are a good many firms in this country who continue to paint engines, machine tools and the like, with rainbow hues, stripes and fresco work, and then to cap all, apply a coat of varnish. It will perhaps be too severe to say that any one competent to understand or do good fitting never finishes a machine in this manner. It is provincial, as they say in England, a very good term for which we have no synonym in use. It means as things are done in the provinces, or, as we sometimes say, in the "back woods."

This matter of paint is occupying a good deal of time, but one more point in connection must be mentioned, that of what is technically called "filling," meaning paste to fill up the pits or grain on the faces of castings and render them smooth. This is an excusable element of ornamentation or finish, and lends a great deal to the appearance of work.

There has been a long period of effort to produce a filling compound that was hard, impervious to oils, and would adhere to cast-iron surfaces. This has now been accomplished, and it has become the custom to fill or flush the surfaces of fine machine tools, dynamo frames and other work that is exposed in conspicuous places.

An old refinement, now nearly gone out of use, was to cut flat surfaces after they were filled, to a perfect plane with pumice stone, which when used with water would abrade the filling material. A proof that such a method of finishing the surfaces of machines is one of good taste is its acceptance with good engineers, who could not without prejudice accord real merits to a machine decorated with colors, stripes or other ornament. It is merely completing what is striven for in the foundry, but is not attainable in the process of moulding and casting.

The best method of preparing machine castings is to clean them completely when they leave the foundry, the green-sand castings by "pickling" in acid, trimming and then painting them thoroughly before they are worked. This last is a Philadelphia custom, and I am unable to explain the effect it produces, that is, cannot account for the appearance after the castings are handled and worked. They seem smooth all over as if they had been rubbed, and are in a nice condition for subsequent painting, but this is not the only thing gained by painting the castings in a rough state. The surfaces can be accurately "lined" for working. Without painting it is difficult to make visible lines to work to, but is quite easy when the surfaces have been thus treated.

Pickling, which means immersion in diluted sulphuric acid, is to remove the scale by setting up corrosion on the surface of the iron beneath, causing the burnt scale to fall off, and afterwards washing the castings in water to remove the acid. The means employed are various, from applying the acid liquor with a swab and setting the castings out in the weather to cast the scale, to providing large wooden or lead-lined vats in which a crane load or a large cage full of castings can be lowered and raised out, after which they are washed with a hose, or what is much better, immersed in fresh water.

With this much in respect to the surfaces of work, we will now turn to the matter of ornament in form, and this in so far as positive ornamentation is soon disposed of, because in the better class of

works at this day there is general application of a rule I once saw posted up in a draughting room twenty-five years ago. It read thus: "Not an ounce of iron is to be used for ornament."

Now that this matter is in mind I will quote some more of the same rules which formed this unique collection. A second was: "No deflecting springs of any kind are to be used on machinery made in these works." Another one: "No screws less than three eighths of an inch are to be used for any purpose whatever, and no screws with slotted heads." Also: "All screws three fourths of an inch and less in diameter shall have square heads, and all screws of larger diameter hexagonal heads."

These rules were carried out in the works for many years in which I knew them, and probably are to this time. The first rule quoted, the one in respect to ornament, certainly is, as the published drawings of the company will show.

This term ornament does not include symmetry, that is, as an integral or, as we may say, an inherent quality, but one capable of different interpretation by different people. For example, a skilled person in looking at a machine recognizes, unconsciously perhaps, the lines of strain, and to his eye the symmetry of framing depends on how nearly the material is disposed along these lines. On the other hand an unskilled observer cannot see a structure in this light. His impressions must arise out of comparison, and a machine seems symmetrical or otherwise as it harmonizes with a house, a plant or an animal. A Grecian or Corinthian entablature is to him a thing of symmetry, only exceeded by a cast iron eagle perched on the top.

Now it need not take long to decide which of these points of taste should be kept in view, and it is a proper thing to consider here, because design and finish in respect to symmetry and propriety nearly always arise out of the administration of a works. The proportions, material and functions, may be left to the engineer or draughtsman, but the owner or manager manages the paint and ornaments.

Sir Joseph Whitworth, who is considered the originator of the hollow form for machine frames, used an illustration during a lecture delivered in Glasgow, about forty years ago, that did more to modify this matter of ornament and the design of machine frames than a whole technical treatise would have done at the time. He said, holding up his hand before the audience: "See how nature designs her machinery. The main members, the bones, are hollow, and there is not a particle of material used for ornament. See how the

corners all have fillets and the contour is smooth and symmetrical."

This is quoted from memory, but is substantially his words. At this same meeting was shown for the first time his surface plates that would adhere together when the air was excluded, also his famous gauges that would "slide and drive," that is, the pins would slide loosely in the collars until they were stopped, or held still for a time, and then had to be driven out by force.

To Messrs. William Sellers & Co., almost as much as to Sir Joseph Whitworth, belongs the credit of dispensing with ornament in machine design. It is true he preceded, but it was in an environment more flexible than that of Messrs. Sellers & Co. The idea has now spread until, as before said, the rule of "not an ounce for ornament" will apply in many if not most of our best works.

6

WORKS ADMINISTRATION.

Lectures before the Students of the Leland Stanford Junior University, Palo Alto, California.

BY J. RICHARDS.

No. 6. December 5th, 1895.

SHOP FOREMEN.

In the first lecture the ideal foreman was mentioned as a mythical person, and is so if he be expected to perform the duties commonly ascribed to this position, but at this day a good many of the duties once performed by a foreman have disappeared. The draughtsmen have taken his place. I can remember very well when a foreman gave out all kinds of instructions for the work in the smaller machine shops in this country. The drawings, if any at all, for use in the machine shop consisted of general elevations in two planes, abundantly tinted with colors, but no dimensions marked. These were supplied to the foreman, who laid out the work, and every little thing had to come under his notice.

He was responsible for the work, the performance of the workmen and for the proprietors also, because the supplies, discipline and everything throughout was under his charge. He alone was responsible in an executive sense, and the man on whom all depended. He got the credit of success, and bore all the odium of mistakes and failures.

With detail drawings came new conditions. The foreman interpreted the drawings when they were obscure, but responsibility was shifted to the draughting room and to specifications, but the foreman found still quite enough to do in other ways, and remained an authority for many things that cannot enter into drawings, but under the present system in machine works the general foreman's executive duties have gone over to a manager and special foreman, or leading workmen set over departments.

I think useful suggestion may arise out of some personal experience in respect to foremen. I had the misfortune to rise to this function at eighteen years of age; not over a great charge, but one of some responsibility, and from then on for twenty years or more was associated with the methods of a general foreman, and could not help noticing various "hitches" that arose in that system.

Then occurred some experience in Europe, where the methods of organization were different, and not applicable, as I supposed, in this country, but in 1884 when a business founded in San Francisco had grown up to employ a hundred men, this matter of a foreman began to assume a problem of much difficulty.

The work made was machine tools, steam engines, hydraulic apparatus and mill gearing or general work, it might be called, consisting of shafts, pulleys, special work and repairing; so there were four separate classes of work carried on, besides the shop departments of wood work, pattern making and forging. Several foremen, all of them fairly competent men, were tried, but it was found beyond their powers to manage the different departments. A man conversant with steam engines did not understand hydraulic work, and one who could manage the hydraulic department could not deal with machine tools or steam machinery.

Finally the shop was divided up into sections under five workmen, selected from each branch of the work because of their skill, and these men were paid extra for acting as the head of their department and being responsible. The shop machine tools so far as possible were set off to these departments, and such tools as could not be segregated operated first for one and then another department, being for the time under the charge of the foreman in that division.

The men were all young, ambitious, and for many years this went on without a clash, except the first day, when one of the workmen came into the office to find out who he was working for. He was informed that this could not be determined in the office, but his right to ascertain was fully conceded, and as there might be

some difficulty under our system he better go at once to some other shop where there was but one foreman. This was the first and last case of the kind. An arrangement of this kind exists in the case of contract work, or other systems of an analogous nature, both in this country and in Europe, indeed has to exist where workmen are responsible for what is called discipline or authority.

In a very large works there is commonly a staff, as at the Union Iron Works, in San Francisco. There is a manager over all, then a work's superintendent of the fitting or machine department, a marine superintendent, a shipbuilder, chief draughtsman of the engineering department, and one of the shipbuilding department, an electrician, and so on. The division of duties is not often the result of a concerted plan, but follows generally as a matter of evolution in each works, because the division of duties is very different in various kinds or branches of work. The general foreman of former times has disappeared.

The terms discipline and responsibility have been several times used, and in these is to be found the key to management in a large works of any kind. In a former lecture it was attempted to show that the efficient performance of duty depended on responsibility, and the more the subject is investigated the more will this become apparent. The same rule applies to discipline, which is sometimes a very difficult matter to deal with in a works.

I doubt if this can be made apparent by words alone, but it will become a very tangible portion of managing duties in future, as you will find, because an aggregation of people all striving to better their condition, improve their skill and position, are necessarily in competition one with another. It is a law of nature, and inseparable from aggregated or community life, extending to the brute creation, and even down to insect life.

Jealousies arise, and to manage so as to maintain harmony among a body of workmen and the staff of a works where there is no defined rules of law to guide, sometimes surpasses human powers. It is an ethical study, which if perused would lead far away from the subject under discussion, but to make it more clear, and to gain suggestions, I will go outside of the industrial field for some illustrations.

About thirty years ago, Dr. Holbrook established at Lebanon, in Ohio, a normal school, the purpose of which was to prepare teachers for the schools in that State, and the Doctor being quite a student of sociology hit upon a happy expedient of avoiding the cares of

discipline. The students, who were mainly adults, were assembled at the beginning of each term and informed that the Doctor and his aids had quite enough to do in giving instruction, and the school must govern itself. He recommended the adoption of formulated rules so far as these would apply, to be voted for or signed by the students, which has since been done at the beginning of each new term, and the scheme has, so far as I know, been a complete success.

The other extreme, that of authority in maintaining discipline, exists at sea, where a commander is clothed with absolute authority over the crew of his vessel, amenable to the laws of his country when he reaches a port, but while at sea he is unrestrained in the exercise of any reasonable or even unreasonable function. By tradition, superstition and necessity the system is successful, but is not one from which suggestion can be drawn for the management of a works.

One other example can be cited, showing that the natural tendency of people is to order and discipline. In London there are a large number of places of amusement, called music halls, most of them quite respectable, and all of them extensive. The admission fee is small, and the risk of disorder is great even in that city, where order is very rigidly enforced. It was discovered that the best way to maintain order in these public music halls was to make the audience responsible. A chairman, representing the audience, sits in front of the stage facing the people, he announces the plays, criticises the performance, and apparently controls everything on behalf of the audience, to whom he appeals in case of a dispute. The theory of the scheme is correct, the teachers in a college or school, or those who have to conduct a works, should not be taxed with the maintenance of discipline and order among their pupils or workmen.

In industrial establishments rules relating to discipline should appeal to the self respect and responsibility of those to whom the rules are directed. Posted notices of a paternal or arbitrary form commonly do no good, and frequently a good deal of harm. When such posted rules are required it is easy to put them in the form of an argreement or request, and to say that the owners or management deem such rules expedient for the good and interest of all concerned.

It must be remembered that at this day in the higher class of skilled industries, workmen occupy a position quite different from former times, and sometimes outrank by education and a fair social

standard those who employ and manage, but even if this were not the case there will be found much truth in the old French adage that "courtesy costs nothing and buys a great deal."

APPRENTICE LABOR.

Those who have during the past twenty-five years had opportunity of observing the matter of apprentice labor have seen a great change in the relations of apprentice work, amounting to a breaking up of the old system, and it cannot be said that a new one has taken its place. The causes of this are not far to seek. A large share of the skilled endeavor to be dealt with has become a portion of what we call a technical education, and the things to be learned are different, calling for different faculties, and for mental instead of manual skill.

On the Pacific Coast, where most of you expect to reside and devote your energies, the conditions of apprenticeship differ from the Eastern States and from other countries. Indentures are less required, because there exists a sentiment, and also a kind of rule that prevents apprentices from leaving one shop and going to another one. He will not be employed if it is known that he has not served out his term where he was engaged. This is a very good custom, and its best feature is in the avoidance of regular indenture, which on the grounds of experience I must say is very objectionable, because bound obligations either way do not secure such good results as free service.

The method of a free apprentice service is presented with some temerity, because I am not aware that it has been tried to any extent outside of a business where I have been connected, but thus far it has proved altogether satisfactory. The method is as follows: Boys to learn a branch of constructive work, that is, machine fitting, pattern making, forging or foundry work, were required to reside in a permanent home, and to have gone through the public schools.

They were taken for one month on probation, at the end of which if satisfactory their parents were sent for and the rules explained. Apprentices were expected to remain in the works from three to five years, as they might choose, and not to leave unless for reasonable cause. The same rule applied in case of their dismissal, a reasonable cause had to be given. The wages paid commenced at fifty cents a day. We had no use for a boy who could not earn that much at the start. From the beginning on to the end we assumed absolute control of wages, and these were made to

depend on how long the apprentices remained at one kind of work after they had gone through some months of knocking about, as it is called. In the fitting shop a boy who would remain continuously at a planing machine or a lathe for a year might at the end of that time be receiving six dollars a week, and for a second year nine to ten dollars a week, but if he shifted to a new kind of work his wages would go down again until he caught up in expertness. Such changes were made at the request of the apprentices or their parents, with whom we were careful to keep in communication.

Difficulties seldom arose, and no apprentice ever went away whom it was desired to keep. If it became necessary, as it did in a few cases, to discharge the apprentices, this was done in a way to not hurt their feelings or injure their hopes in some other undertaking. The system was one of fairness, kindness and equity, throwing as much responsibility as possible on the apprentice himself, or on he and his parents.

This method was tried in Philadelphia and in San Francisco with a result, or at least a belief, that such apprentice work earned a great deal more than it would have done under an indenture system. It might not answer so well in a large works where personality is nearly eliminated, but it certainly answers in a small works when carried out in the manner described.

How skilled trades are to be learned in future is not very clear at this time. The opportunities of learning are all the time growing less in the way of acquiring manual skill, and the need of manual skill is at the same time and in the same proportion becoming less. Perhaps the future outfit will be the technically trained apprentice, the machine, and the common laborer.

Thomas Carlyle in *Hero Worship*, twenty-five years ago, foretold the influence of tools in the human economy. "Man," said he, "must be defined as a tool-using animal. The true epic of our time is not arms and the man, but tools and the man; an infinitely wider kind of epic." Tools have in a great part substituted human skill; machinery has replaced his muscular power and the apprentice of the future will stand in new and different relations.

SHOP PROCESSES.

This head will lead us into a very wide field, in which there is little or no authority, written or other. It is a subject that must be treated empirically. There are many ways of performing things, some of them good, some better, and one the best. These degrees

of comparison are not absolute, they depend on circumstances. To illustrate the difficulty of setting up standards, since the last lecture I had occasion to set a Japanese at work with a hand saw. He made an abortive attempt, and then said: "Teeth are the wrong way, in Japan saw pull, no push." Of course I laughed at this, and for the moment thought how stupid such a method was, but later on, and now, I am inclined to think the Japanese are right in this matter, and we are wrong. Let us examine it a little.

In the first place, if a saw is pulled, instead of pushed, it is in tension, and will not double or buckle as our saws do, and can be made much thinner, perhaps not over half as thick, and be operated with proportionately less power and waste. The cutting pressure is much less in pulling unless a saw is weighted, but the pressure is uniform, and a saw will not cut unless sharp, as it ought not to do. Again, pushing as a form of manual power is less effective than pulling. The limit in this direction is the leaning weight of the body, but in pulling one braces with their knees, feet or one hand, and attains in addition to the leaning weight a muscular effort of equal or greater force.

I have seen the Japanese carpenters at work building their place in the Centennial Exhibition of 1876, and remember that the sawing was rapid, true and seemingly less tiresome than our pushing method.

In a former lecture mention was made of the advantage of painting rough castings, so they could be easily lined or laid out for working, and as this matter is directly a problem in shop processes and of administration it will be a proper one to begin with.

In England, and, as I believe, in Europe generally, also in Philadelphia to a greater extent than elsewhere in this country, castings and forgings are lined or laid out by the fitters, and the men who operate machines work to lines instead of drawings. It is easy to see what a wide difference this will make in the division of work and the relations of workmen. The fitter or, as we say in this country, floor hands, vice hands or bench workmen, are by this system made responsible as the leading mechanics, who assume nearly all the responsibility. The machine attendants, those who turn, plane, drill and mill to lines are thus reduced to a lower grade, because of being relieved of responsibility, and receive less wages accordingly. This is one system.

The other, which is most common throughout this country, is to

distribute drawings to all the machine workmen, and have them lay out their own work to the drawings. If a piece is to be planed, the man at the planing machine examines the drawings and works out the finished forms to the marked dimensions. The same in other operations. while the fitters, which is the shorter and better name, are furnished a general drawing from which they assemble the parts and erect the work.

As a problem of administration, or of method, the first system is certainly best, as it permits better organization, and leads to various advantages that may be summed up as follows:

Work is much better laid out by the fitters, who have each part and its relations in mind, also have proper facilities, such as scribing tables, gauges, straight edges and so on. Machine workmen when laying out work must leave their machines idle during the time, and thus reduce the capacity of a shop, or else render more tools necessary. There is ten times the liability to errors, because only a few machine men can understand the completed or assembled work. The other system sets a number of men at work independently, and this diffuses responsibility, also causes it to be shifted from one man to another. The amount of work that can be performed on the diffused method is much less than when the fitters lay out and arrange the work in proper sequence.

The single argument in favor of the diffused method is that it is a democratic one, tending to an equality among workmen and affording advantages to learners, but a works can no more be managed on a democratic plan than a ship or an army can. The sole attempt at this method of administration that has met with success — and even that is a question — is in framing rules and laws for popular government, not their execution, because that, even in democratic countries, must be done by authority.

Any one who has seen a casting or forging lined for working by an expert mechanic, will be convinced of the correctness of the system. The main implements are a flat table and a set of surface gauges. Sometimes pieces, especially forgings, are bolted to an angle plate, or an angle plate is bolted to the pieces, so they can be turned at will and lined by surface gauges, in two planes. It is a very interesting kind of work.

Cylindrical forms have within themselves the elements of determining their dimensions, and do not require laying out, except for longitudinal dimensions, hence machine men work from detail drawings.

While speaking of shop processes and methods, such as will fall under or be determined by the management, I will call attention to a curious circumstance in turning operations.

In this country the invention and wide use of milling or turret lathes, commonly called screw machines, preceded by at least twenty-five years the use of such machines in other countries, and even now there is but a limited use of such machines elsewhere, compared with American practice. These machines can be distinguished as milling machines for cylindrical work, that is, the milling tools embrace or surround the work and the capstan or turret is set in the axis of the lathe spindle, no rear spindle being employed. In such machines there was a cutting-off slide, but no arrangement for using other tools except those for milling, cutting screw threads, and so on.

In England a little later on, or about twenty years ago, there was invented and introduced a heavier class of machines, called turret lathes, intended for the same kind of work, but operating with common lathe tools. The turrets that held the tools were set at the side of the work and the line of the spindle, or rather were mounted on a cross slide, so as to be set transversely at any point across the lathe, and this permitted a rear spindle and sliding head like a common lathe.

The results attained were remarkable, and such that after a time the turret-lathe work, that is, such as could be done on these machines, was drawn on separate cards, and went to a department called the turret-lathe room or shop, where the work was done mainly by boys. The limit of length was not, as in the American machines, what the milling tools could reach over, but was up to two feet in length for the larger machines. In fact there was all the functions of a common engine lathe with turret elements added.

In this country not much attention was given to these turret lathes until the last three or four years, when the Gisholt Machine Co., of Madison, Wisconsin, began their manufacture in a very improved form, and the results attained are remarkable. I happened on one of these lathes recently in the Union Iron Works, at San Francisco, and was informed that on duplicate work the result was astonishing, both the amount and accuracy far exceeding what could be done on the tools previously in use.

I have spent some time in this matter to show how slowly methods spread, and how divergent practice is in what may be called standard operations.

In machine shops at Philadelphia, where the practice is certainly as advanced as anywhere in this country, work is not chucked on lathes, that is, work to be bored is not mounted on face plates and revolved for boring. This work is done with bars, even when performed on lathes, but two hundred miles away, in New England, they make and use chucking lathes for similar purposes.

STANDARD DIMENSIONS.

I do not think it necessary to dilate on the advantages and economic effect produced in a works by employing a system of standard dimensions. This matter has, no doubt, been or will be presented here by Prof. Smith, and to argue the expediency of adopting a system of standard sizes in a works will imply that you might not do so, and that is not supposable at this day.

I have used up a good deal of my life's work over this subject, and, as I believe, was the first to found in the United States a system and manufacture of standard gauges, now the American Standard Gauge Works, at Wilmington, Delaware, and by my son-in-law, Mr. James A. Taylor, who has been identified with this business since 1877.

The first set of caliper gauges and a corrective cone, it is called, to keep the gauges in adjustment, were made in 1862. The first measuring machines were made in 1878, pin and collar gauges about the same time. A successful manufacture of fixed caliper and internal gauges was finally accomplished about the same time, but a great many American shops had previous to that supplied themselves with English gauges, made by Whitworth, at Manchester. Now there are several makers in this country, but much the largest number of gauging implements are made at the American Standard Gauge Works.

The employment of standard sizes in machine fitting has two objects; one a saving in the cost of construction by the organization it permits, and the other the effect produced on values or prices. The effect on shop manipulation is to permit interchange, and secure good work. If everthing turned or bored had to be trial fitted there could be but little division of processes in a shop, in fact a gauge system is indispensable up to a certain point in any but a very small shop, but the methods of attaining gauge sizes are various and some of them incredible. In San Francisco in former times, and yet, as I believe, in many of the shops there are turning gauges based on the size that round merchant bars of iron or steel will finish, and as

these bars are in this country rolled to standard dimensions, as nearly as possible, the finished sizes are something less, awkward dimensions that bear no relation to any standard measure. A reason assigned for this is that it prevented interchange of work made in the different shops, and forced purchasers to have repairing and additions from the same place where the work was originally made.

It is very singular that the price of machinery has not been much affected in this country by its parts not conforming to standard dimensions. It shows a wonderful neglect on the part of purchasers, who should require this in every case, because, all things considered, there is a great difference in the value of work made to standard sizes and that which is not so made. It is an implied condition in contracts in most parts of the world, and is a sufficient ground for rejecting work made by contract that does not conform to standard dimensions.

To keep this subject under the head of shop processes, with which we are now dealing, I will say that the first thing provided in the outfit of a machine works should be a set of gauges. They will be required even before any work is done to test the dimensions of purchased implements, and the next thing, following gauging implements, are turning mandrels.

It will no doubt be a new proposition to assume that the foundation of a gauge system in a works is the turning mandrels. These are the executive element, so to speak, for maintaining and compelling standard dimensions for cylindrical work. Suppose, for example, that in a works where there are no gauging implements of any kind there is introduced a set of turning mandrels, about thirty in number, from ½ inch to 4 inches, all ground to standard size, and that there are no other mandrels to be used. Every piece requiring to be turned would have to fit these mandrels, otherwise it could not be put into a lathe.

If there were no standard gauges the mandrels would become such. All kinds of cylindrical work would be turned to the mandrels, which represent in every way pin or internal gauges, and an uniform system of sizes would arise out of the mandrels alone. In fact a set of fixed caliper gauges, and a set of true turning mandrels made from the gauges, represent a tolerably complete set of gauging implements if there is some reference from which the calipers can be tested to see that they remain true.

Double or even triple sets of the sizes most used should be provided, but there is no loss in this, except a trifling investment, the

wear and deterioration by use being the same whether it falls on ten or thirty mandrels, a matter that will be again alluded to in connection with some other implements.

In respect to the method of preparing mandrels, I will say that up to one and a half inches in diameter they should be of cast steel, hardened all over and ground, reduced at the ends and flatted on the sides for driving clamps. From 1½ to 2½ inches they can be made of shear or machinery steel, the centers made in plugs of cast steel inserted and hardened, or the ends can be well case-hardened. From 2½ to 4 inches mandrels can be made of soft steel or iron, but in all cases the centers should be inserted. If the mandrels are of iron the center plugs can be welded in and hardened, after which the mandrels can be turned or ground to size.

It may be considered a severe rule to make holes in which mandrels must drive, and it is so, even with the aid of sizing reamers, but it is practicable and is necessary. Variations of size to one ten thousandth of an inch are clearly preceptible by means of common calipers, and can be felt to much less with rigid calipers or calipering gauges. The necessary fits in a machine shop are far within the thousandth of an inch, that is the difference between loose, driving and shrinking fits come far within the thousandth of an inch, as you have no doubt learned from other sources.

As difficult as it is to secure fits or diameters, and even the parallelism of holes, these are more easily attained than straightness. There seems to be some inherent cause not very well understood for deviation in the straightness of holes, and as a means of correcting this, and also the diameter and parallelism, reamers are employed.

Reamers constitute the third element in gauging implements to maintain standard sizes, that is, in the cycle of adjustment, or proving gauges; calipers come first, then mandrels, and third reamers.

These are manufactured as an article of trade in three forms, solid, adjustable and shell reamers, with which most of you are familiar, and I will not consume time to point out the difference, because all are analogous in nature, use and objects, but I will here introduce a little heresy by asserting a belief that the reamers as now made are inferior to the very oldest form, the single blade or D reamer that dates back more than fifty years.

Of course no one is bound to believe or adopt opinions expressed in these lectures, and there may be recommendations and views at

variance with common or accepted practice, but such views are honestly entertained, and whenever presented here will be fortified by observation or experience. With this precaution I will venture to say that the old one-blade reamers made by John G. Bodmer, in 1840 to 1845, are in both theory and working results better than the multi-blade reamers of our time.

All true cutting edges require an abutment, a base for guidance or determination, it may be called. In a lathe such guidance is given by the traversing ways. The same in boring with common tools, the abutment or guidance is derived from the axis of bars or other surfaces, and not from the work itself or from the new surfaces being prepared. There is another class of implements, notably all kinds of drilling tools that derive their abutment from the surfaces being cut, and without extraneous support. Such implements never do true work unless the abutment surfaces are large and non-cutting.

I am afraid this is not very clear, but it will become so if you will observe common implements and apply this rule. A screw top, for example, derives its support or cutting abutment from its cutting edges, and is notoriously a contrary tool that will deviate in any direction, and must be guided by the eye or by some contrivance, such as a tap guide. A fluted reamer with edges only for abutment is not much better in respect to support, and may deviate in the same way, unless the amount to be reamed out amounts to merely scraping.

The old D reamer had ample guidance around three fourths of its perimeter, was adjustable, so the body when made, as it should be, to a standard size furnished a complete abutment and support for the edge. There was also ample clearance for the chips to fall out, which is not the case with modern reamers when cutting out more than is required to merely true a hole.

I mentioned these reamers in connection with John G. Bodmer, who no doubt contributed as much to machine-tool discovery and improvement as any one who ever lived, and of whose work I expect to say something more in a future lecture, but the D reamers have come down to our time.

Some years ago when in the works of J. Morton Poole, at Wilmington, Delaware, they were pressing the axes into chill rollers about thirty inches long. The shafts were about three and a half inches in diameter, and each went in with nearly the same number of tons pressure, which could be read from a gauge on the hydraulic

press. I was astonished at this, and asked Mr. Poole how it was possible to bore the rollers so exact. "It is the reamers," said he, "come and I will show you." He went into the tool room, and there, each in a separate box, were single-blade reamers as long as the rollers to be bored. Mr. Poole explained that a jet of water was sent in along the blade, so that all the chips were washed out as fast as made.

Some years later, when in the works of Mr. William Asquith, at Halifax, in England, I noticed the perfection of the holes made in all kinds of work, and inquired how these holes were finished. He, like Mr. Poole, took me to the tool room, and there again were the old D reamers, which he assured me had survived after various other kinds had been tried. These are two cases now in mind, but there are many more.

The great gun tubes, bored from solid steel, are finished out with D reamers, or at least this is the case at Sir William Armstrong's works in England.

Making holes is the main thing of all in machine fitting, external work is done by positively moved tools, and is easily made as true as the guiding ways, but holes or internal work is mainly done either by abutment in the holes, or from extraneous supports that are by no means as rigid and true as in exterior work, and no implement without other guidance than its cutting edges can do true work.

In making a steam engine, the most difficult operation is to produce a cylinder that is straight, parallel, and smooth in the sense of not having ridges or pits.

Summing up what has been said of standard dimensions, it will amount to a recommendation, that in equipping a machine fitting shop there is required a set of fixed calipers with internal gauges combined; a corrective standard for these calipers; a set of accurate turning mandrels; and a set of single blade or D reamers.

With these implements, all of them simple and inexpensive, one can rest assured of work being kept to standard sizes.

7

WORKS ADMINISTRATION.

Lectures before the Students of the Leland Stanford Junior University, Palo Alto, California.

BY J. RICHARDS.

No. 7. December 12th, 1895.

It was at first intended that this lecture should be in a sense separate, or given at the end of the course, but on re-consideration it seemed to be, except the historical part, so intimately connected with shop processes as to be included under that head. It will consist of two parts, the first being some remarks on metrology or standard measures, and the second on gauging implements derived from standard measures.

It is a curious and even anomalous fact that throughout the realm of nature there is no uniformity except in the element of time. The inevitable laws that govern forces and motion, the endless cycle of causes and results that form the basis of the physical sciences, point to uniformity in matter as a sequence or condition of these invariable phenomena, but this is not the case. There is no uniformity in the matter.

No two people are alike. No animal, tree, shrub, plant, leaf, or even a blade of grass, has its precise counterpart in nature. Among

a thousand faces that we know, each is distinct, and among the millions that we do not know this distinction goes on without any limit that we can conceive of. It is possible that no two grains of sand are precisely the same. There is no regularity of temperature or weather, no uniformity in matter organized, active or inert, so there is no fixed material basis from which a natural standard for metrology can be derived. Distilled water, we may say, is uniform in weight at some assumed level, the surface of the sea for example, but how are we to determine a specific quantity of distilled water or other liquid, without some means of measurement?

Lineal measure must be the base of all. By this is determined weight, capacity, surfaces, solids, and indeed all that is called measures. The metrical system is an illustration of this; the meter, an arbitrary lineal standard, is the base of the whole metrical system.

Some centuries ago this difficulty of standards became apparent, and there was a search extending over about two hundred years in attempting to derive from some natural source a lineal measure that could be appealed to in case of doubt, or the loss of standards derived therefrom.

This search for a natural standard for lineal measure in England and France forms a very interesting history that we need not follow out here, farther than to say that the two nations started out on different roads that after long and tedious experiment came together again, because the search was abandoned by both countries.

The English scheme was to derive a lineal standard from time, or, as we may say, from the motions of the planets. Time is a constant and uniform element in the great economy of nature, divided with accuracy down from years to seconds, or, as we may say, with present knowledge, from centuries to seconds, and a measure derived from time could always be reproduced.

The method attempted was by the vibrations of a pendulum in a vacuum or at sea level in an undisturbed atmosphere. This was a very ingenious idea, and came near settling forever a standard for lineal measure. As a pendulum swings in equal time, irrespective of range, it is easy to adjust one to beat to seconds, and if this length could be translated into a measuring implement a similar standard measure could be derived in any part of the world at any time.

There arose, however, some serious impediments in these experiments, one of which you can easily imagine; that of determining the length of the pendulum after it had been adjusted to beat seconds.

The method was to place fine pivot points at both ends of a symmetrical bar of metal, and then reverse it, to swing first on one end and then on the other, but there remained still the difficulty of transferring this measure, so the scheme was finally given up after half a century of experiment.

The French people attempted to derive a lineal standard from material nature, the ten millionth part of a quadrant of the earth's meridian. To determine this a degree of longitude was measured between Dunkirk and Barcellona, and the meter was derived from a subdivision of this length, but there arose great contention over the method and results, and the French then, as the English had done long before, abandoned the scheme of a natural standard, and legalized the particular metrical standards then made, and took the required precautions, as in England, to deposit duplicates in different places, so that their loss could not occur. There was a great ceremony over this event during the reign of Napoleon II, and this arbitrary standard is, as you know, fast becoming that of the whole world, as it ought to do with all possible haste, being decimally divided.

When standards are arbitrary it is nonsense to talk of a national one. One standard is just as good as another in so far as being an authority. If any nation had succeeded in determining a natural standard, the case would be different, but an arbitrary one may be a yard, a meter or any other unit. There is nothing national about it, and cannot be.

The English, and to some extent the American idea of a meter is that it is a French measure, because France first adopted this unit, but being an arbitrary measure it is not French any more than it is English or American. It is only a matter of agreement, as the English yard is with its division into inches and feet, with divisors of three and twelve instead of by ten, as we compute in numbers.

I am sorry that the time at command does not permit more to be said of the curious facts and procedure that are embraced in this history of standards. It is extremely interesting, but not very useful in a practical sense, unless to dissipate some notions commonly entertained about natural standards.

The legal standard in this country is the meter, legalized in July 1866, decimally divided downward to the millimeter, and multiplies upward the same, to the myriameter, but by custom, and following the British measures, our machine work is mainly with measures corresponding to divisions of a yard, with divisions downward of three

and twelve, as before remarked, stopping at an inch, which is twenty times too large for convenience, and going up by factors of 5½, 40 and 8 to a mile, all of which is as absurd as it is inconvenient.

Other measures of weight, capacity, surfaces, solids, and so on, are as bad or worse, because we have two standards for weight and two for capacity, both in common use, divided in a manner that conforms to no conceivable system of order or relevancy, and explainable only on the grounds of accident, dating from a time and from circumstances that have nothing to do with modern methods, a tradition that would be out of place in the realms of imagination, to say nothing of the exact arts and sciences of our time.

The gauging implements now in use in this country, and by means of which the dimensions of machine parts are determined, are derived from the British yard, expressed in inches and fractions of the same, mostly fractions, indeed all fractions, except for four implements out of a set of thirty to forty pieces, as any table of sizes will show.

These gauging implements consist of movable or adjustable calipering machines, fixed calipers, pins and collars, internal gauges, test rods, reamers, mandrels, and so on, all adjustable to various degrees of accuracy; for example, to a five or twenty thousandth part of an inch in classes that are sold at different prices according to the accuracy guaranteed by the makers, as the published lists will show.

In 1860, when my connection with this matter began, there were no gauging implements in this country, except Whitworth pins and collars, imported at an expense of $400 to $800 a set, according to the number of sizes embraced, and these gauges were found only in a few of the largest shops. Such gauges are only for reference, from which other implements are made, hence did not meet the real want of gauges that could be given to the men for practical use. Some firms had made forged caliper gauges with round or curved contact points, but there was no manufacture of standard gauges in this country, nor was there in England, except pins and collars, down to 1878, as some future explanations will show.

With this much in respect to the derivation and nature of gauging implements, I will now revert to the history of their manufacture in this country, in so far as I had a part in that matter.

This is done with some diffidence, and the excuse for introducing a matter so personal in nature must be the great interest I once took

in the subject, and a belief that among the few contributions I have been able to make to the advancement of constructive practice, this is by far the most important and the one I especially desire to be known, if any at all, when my work is ended.

In 1862, when foreman in the works of the Ohio Tool Co., at Columbus, Ohio, I had occasion to make some duplicate work, and not having any means of attaining standard sizes I sent to Jones & Laughlins, at Pittsburgh, makers of cold rolled shafting, asking them to send a piece of 2-inch shafting that would fit the Whitworth collars they used in their rolling processes. A selected piece of this shaft, about one foot in length, two inches diameter, became a standard, from which was derived a series of sizes from one half to three inches, in the following manner:

The cross-feed screw of one of the engine lathes was measured with a rule, and found to be tolerably accurate, the pitch being eight threads per inch. A conical pin of cast iron corresponding to one end of the cone standard, at the bottom of the sheet of illustrations, was put in this lathe and turned in steps by eighths and sixteenths of an inch, the same as in the drawing, but was left a little large. Then a finely tempered square tool was put in the lathe and its edge set true or parallel to the work. The cross-feed screw was provided with a disc divided into four parts, with a detent that would lock it at these four points. The two-inch step on the cone was thin turned, or scraped until it would caliper the same as the piece of shafting before mentioned. Then the tool was advanced a quarter or half turn and fed over the next step, and so on down to the half-inch size.

The same process was gone through from the two inch step upward to the three-inch one. This cone was mounted in an inclined position on a cast iron base and became a standard for sizes, resting it is true on a very uncertain standard, but much better than no standard at all.

It was soon discovered that fixed calipers were required, and I proceeded to make these by cutting out lune formed pieces from sheets of cast steel, also had some made from forgings of cast steel. A set of these gauges, about forty in number, was sent to Messrs. Brown & Sharpe, at Providence, Rhode Island, to be ground to size with flat points, and I believe were the first gauges made in this manner. Previously the points were made curved or convex, offering only line contact to withstand wear. A set of these gauges were taken to Messrs. J. A. Fay & Co.'s works, at Cincinnati, Ohio, in 1865, and are no doubt in use there at this time.

Patents were taken out on the lune formed, flat point calipers, and on the corrective cone, in 1867, but various circumstances prevented farther work on gauges until 1869, when I went to Philadelphia to found if possible the making of my gauges and corrective standards.

Everyone regarded the matter of gauges as a mystery, and set small value on the audacity of a young man from Ohio, who proposed an innovation on the Whitworth gauges. I learned, as afterwards proved almost true, that the making of gauges was a mystery, and that no one knew how the processes were carried on, but the main impediment was that I proposed a new system.

I went into various shops to explain how pins and collars were of no use but as a reference, cost too much for common use, and were a foreign product, but no one would aid or join in such an undertaking, and I went on to England, where at the expense of a good deal of time and money, and such information as could be gathered, the conclusion was that the means I had at command would be of no use in founding such a business, and the scheme was reluctantly abandoned until 1872. Then having more means I concluded to go on again, and rented one of the front offices in the Franklin Institute building, in Philadelphia, and arranged to have room in the basement to carry on the manufacture of gauges.

In this office was prepared the designs and detail drawings for ten special machines adapted to the various processes required in making calipers and corrective gauges. These machines I mention with some pride, are all in use today, and in so far as I know, have not been much modified although others of various kinds have been added.

A contract was made with Baxter D. Whitney, of Winchendon, Massachusetts, to construct these machines, which he did with an accuracy that it would be hard to excel at this day. The work occupied about a year, during which time I was in England, and then came the great panic of 1874, which stopped all productive industry in the way of implements of every kind. No one could conceive of what was to come; shops were closed, and skilled mechanics had to beg for their bread.

My gauge-making machines were coated with lead and tallow, boxed up carefully, stored away at Winchendon until August 1877, when they were sent to Philadelphia, set up, and the gauge works, as we supposed, were founded, fifteen years after the first outfit of gauges was made at Columbus, Ohio, but the matter had

been followed in one way or another all this time, in this country and in England.

In 1875 or 1876, Prof. John E. Sweet, at Cornell University, began and carried out there some very complete experiments in making standard calipers that deserves notice and commendation in any history of the art in this country. Some very accurate caliper gauges made at the University were exhibited at the Centennial Exhibition of 1876, with much other mechanism designed by Prof. Sweet that attracted wide attention. The first straight line steam engine for one thing. The calipers were remarkably good examples with broad flat points, hard and parallel, but Prof. Sweet in talking of them dropped a remark that became significant some years later, as will appear further on. He said: "We will not make any more of these calipers."

I will now quote briefly from a paper read before the Franklin Institute, about 1878, when the circumstances were better remembered than at this time:

"It was thought that in a month or so calipers and corrective gauges would be ready for sale, but these expectations were foiled by several circumstances, principal among which was the failure of the measuring machine, fitted with graduating screws made at the Whitworth Co.'s works in England, and guaranteed as to accuracy. This matter had before been thought of, but there was scarcely a doubt that the pitch of the screws was correct. Subsequent experiments, however, proved that not only the aggregate pitch was wrong, and the screws not parallel, but the relative pitch in so short a length as seven inches would not do to depend upon. The screws were, no doubt, as the Whitworth Co. afterwards maintained, carefully made, but the delicacy of measuring tests demands more accuracy than can be attained by the pitch or movement of screws.

The first experiment in measuring was made by preparing six rods of Stubb's wire, the points nicely finished, and the central part covered with several layers of thick soft paper to prevent induction. These rods were carefully fitted into the machine when set at six inches, temperature and other conditions being carefully observed. The rods were then uncovered and fitted into a groove cut on the side of a bar of pine wood, and taken to Messrs. W. B. Bement & Sons' works, where a Whitworth master screw, with the necessary conveniences for testing the rods were supplied, and even the experiments conducted by the firm, who were kind enough to take a great interest in the matter. By careful comparison it was found that the measuring machine in comparison with the screw recorded about one in ten thousand short. This, of course, stopped gauge making for the time. The test rods were then taken to London, and in three separate experiments on different standards, two by myself and one

by Gen. B. C. Tilghman, member of the Institute, it was found that the rods were short, the variation being but little in the three cases, and corresponding very nearly with the less perfect experiment at Philadelphia.

The next operation was to procure four standard test rods, from Troughton & Sims, of London, adjusted to the imperial yard of Great Britain and its divisions, by which the measuring machine in Philadelphia could be adjusted. Such rods were prepared in London with great care by those having access to the imperial standard, and my son, Mr. George Richards, then in England, brought them out to Philadelphia, and began the correction of the measuring machine, proving by combinations of the rods comparing with Whitworth gauges, and other references also by combination. In the mean time another set of test rods were preparing in Manchester, England, and were forwarded to Philadelphia to prove the first set, and also the machine, which had then been tolerably well adjusted."

The adjustment of this standard machine occupied one month's time. The room was kept at one temperature, as nearly as possible, and thousands of readings were taken off, and when finally done, and the screws calibrated, the profile of error was curious to observe, the profile of one screw was convex, so to speak, and the other concave in respect to the axes.

I will remark here that any screw of reasonably accurate pitch can be made to measure or move for delicate measurements if its errors are translated to the reading scale, that is, if the scale or the index point on the scale, is arranged to vary with the errors of the screw. Suppose, for example, that the pitch of a screw varied $\frac{1}{100}$ of an inch for each convolution, either long or short, this would make no difference if the scale from which readings were made was adjusted forward or back $\frac{1}{100}$ of an inch at the same time. This is the method of adjustment adopted for all measuring machines that were made at the Philadelphia works. The errors of the screws were compensated by the indices.

When finally we were prepared to adjust gauging implements there arose another impediment, more formidable still. The contact points of the calipers with flat contact faces could not be ground parallel. The grinding wheels have to rotate parallel to these faces, and pass over them, and as the pressure is as the area in contact, the unavoidable elasticity in the wheels and their mountings, produced a curved surface. Here was an inherent principle involved, an insuperable difficulty that seemed to set at defiance all known methods of manipulation.

I remembered then Prof. Sweet's significant remark, and we applied to him for information. It was as expected. This was the

difficulty he had met with. He kindly came to Philadelphia to aid us with his own experience and suggestions, but there seemed no way out of this dilemma until one day light came from an unexpected quarter.

Mr. J. Morton Poole, Senior, of Messrs. Poole & Sons, Wilmington, Delaware, came into the works to examine the gauge-making processess. At that time I imagine that no one in the world had given so much attention to abrasive grinding as Mr. Poole. He had a laboratory for experiments and the making of grinding wheels. He had collected corundum and other abrasive minerals from all parts of the world, and had an organized and classified cabinet of such minerals. We thought then, and believe yet, that in that laboratory was collected more knowledge of abrasive grinding material and processes than existed among all the makers of grinding wheels in this country, or in the world perhaps. Some of his grinding operations on paper calendering rollers were marvellous, and so intricate as to almost defy explanation. He would grind piles of these rollers eleven in height so as to exclude light between them, and the line of light, as it is called, is commonly estimated at the ten thousandth part of an inch. The guidance to produce this marvellous parallelism and truth was derived from a theoretical axis of rotation, and not from mechanical guides or ways.

Mr. Poole heard patiently an account of our dilemma, and then quietly remarked: "You must grind without pressure; come to Wilmington, and I will show you how to do this." He had by the selection of certain fine grades of sharp corundum, and by certain methods of cementing, produced wheels that when flooded with a solvent of this cementing material would grind without pressure. I do not now remember the composition, and if I did would not feel at liberty to make it known.

The theory, as explained by Mr. Poole, was this: "A new sharp edge does not repel, on the contrary will draw the material to the edge. Now each time one of my wheels turns around a new set of edges are brought to bear, because the wheels are slowly but continually being dissolved by the liquid solution in which they run, or with which they are flooded."

The result was remarkable, also will seem incredible. If a file was laid in front of one of these wheels, pivoted at its center so as to swing against the wheel, and a jet of the solvent solution was turned on, the file when swung against the wheel would remain there, and be ground away without any retaining pressure whatever. This

may arise from the effect produced by the liquid, or other cause than the extreme sharpness of abrasive edges. I do not claim to understand the phenomena, and we were too gratified at the results to press for explanations from Mr. Poole. He prepared wheels suitable for grinding the points of calipers, a thing he had never done before for any one, and extended many courtesies and kind acts that will never be forgotten.

The problem of making fixed calipers was solved, and gauge making rendered possible; first, by Prof. John E Sweet, who discovered and pointed out the nature of the difficulty in grinding the contact points, and by J. Morton Poole, who removed this difficulty by his knowledge of abrasive processes.

As soon as accurate calipers could be ground, orders were taken and the business began, one of the first orders being for a railway works in England, and the second for the Baldwin Locomotive Works, at Philadelphia. It was sixteen years from the time of making the first set of calipers at Columbus, Ohio, and $18,000 had been spent in implements, experiments and other expense.

After the business was founded some other firms at the East took it up, and added what Mr. Taylor called the "theatrical part." The Whitworth system of end contact or touch, it may be called, was disparaged, and apparatus for visual divisions was instituted. Prof. Rogers, of Cambridge University, went so far as to forget the courtesy due to Sir Joseph Whitworth and to deride his "millionth measuring machine."

Sir Joseph Whitworth had made in his works a machine fitted with such accuracy that it would indicate movement to one millionth part of an inch, a thing easily proved and performed hundreds of times, but it was not a measuring machine in the sense of testing or defining dimensions.

I know more of this machine, which I have often seen, than it is possible for Prof. Rogers to learn. It was made by Mr. John Sincock, now of Birmingham, who was for many years in the works of Sir Joseph Whitworth, engaged in the gauge-making department, and who has informed me of the methods of attaining the extraordinary fitting done on this plain-looking machine.

A small bar of metal was poised like a scale beam to vibrate between the contact points of the machine. This bar was set in vibration and the points closed until the friction between them would cause the vibration to cease. Then the pivots were drawn back, the beam set in vibration and the points returned to within one millionth

of an inch of their former position and the beam again set in vibration, which would continue until the points were advanced a millionth part of an inch when the friction would arrest vibration. The machine is in the Kensington Museum, at London, and is no doubt capable of the same demonstration now. The purpose of the machine is to show that surfaces can be so accurately fitted as to not move in stages when such minute adjustment is made.

The standard machine at the American Standard Gauge Works, that weighs about 600 pounds, and has a range of six inches, is fully sensitive to the fifty thousandth part of an inch, as was demonstrated before the Franklin Institute in 1879, where I read a paper on the subject of standard measures, illustrated by various implements and machines supplied from the gauge works in Philadelphia.

The machine is set on balance beams, a necessity discovered in its adjustment. It is covered with a close glazed case, and set where the sun will not shine upon it. This latter matter caused some difficulty during adjustment. The contact points are double, and it was discovered that during the forenoon the rear points facing southeast were loose, and front points were closer. In the afternoon they resumed their normal relation. This was caused by the sun shining through a window at the back of the machine, and is not a matter of wonder at all.

It is a common supposition that the processes of gauge making require great dexterity and skill, because of minute dimensions dealt with, but in a gauge works there is no more care or concern respecting a ten thousandth of an inch than there is over one hundredth of an inch in common fitting. Workmen deal with these small quantities in the most common-place manner, by numerals which represent thousandths of an inch or tenths of thousandths, these being the units employed for all kinds of work

To show that our ideas of accuracy are relative only. I once employed a wood turner from the country to turn wooden vice screws. The heads were about four inches diameter, but these began to increase because of wear in a notched piece of board he employed for calipering. He was requested to turn the heads one eigth of an inch less in diameter so they would fit into the screw cutting machine. He stopped his lathe, and with an appealing look said, "Mister, put that in quarters, I never come down to eighths," in evidence of which he showed us his home-made rule, that was divided only to quarters of an inch. That same man might have been taught in a week to deal with thousandths of an inch.

Nearly all finishing operations in gauge making are performed by succession so as to avoid a rise or change of temperature. If calipers are to be ground, from five to twenty-five are taken at one time, and after a few passes in the grinding machines one is removed and another inserted until a close limit of accuracy is attained. Then the whole are tested by the standards. Each piece after testing is marked with chalk, 2—3—4 and so on, these figures meaning tenths of thousandths of variation from the standards. Those coming within one five thousandths of an inch were taken out as one class and the rest returned to the adjusting room.

By repeated trials the accuracy would increase, and a second class within one ten thousandth of an inch would be taken out as completed. A still higher class had a limit of one twenty-five thousandth part of an inch. This was the ultimate accuracy aimed at in commercial implements. These latter were sold at a much higher price, and were seldom wanted. The expense of adjustment increased very rapidly with the precision attained, much faster indeed than the difference in price, and gauges beyond the limit of one ten thousandth of an inch, were not very profitable to make.

You will no doubt wonder how such implements can be removed from a machine and be replaced again so as to have precisely the same position, but this is simple enough. Everything ground is mounted on centers or points like those of a lathe, but very carefully prepared and the center points accurate and kept clean. The centering points are cut away from the gauges seen in the drawings.

The first use of gauging implements in a systematic way was no doubt by John G. Bodmer, at Manchester, England. Mr. Bodmer was a Swiss engineer, who at his day was perhaps the foremost mechanical engineer in Europe. He was born at Zurich, in 1786, and began his career when young as a millwright, that term meaning then, a constructor of all kinds of machinery. He made his way into Germany and Russia, where he held honorable commissions, and in 1833 went to Manchester, where he founded a machine works, invented and constructed nearly all the machine tools known to modern practice.

I will read a short extract from a memoir of Bodmer, from the minutes of the Institution of Civil Enginers, London, dated 1868:

"Mr. Bodmer approved so highly of the French metrical system of measures that he adopted it, and made use of it in all his drawings and constructions. He also, from the first, introduced it into

his workshops in England; and so far from experiencing any difficulties in this matter, on the part of the men, they understood it immediately, and liked it, at least, as much as the duodecimal system represented by the old foot-rule, and the subdivision of the inch into 'eighths,' 'sixteenths,' and 'thirty-seconds.' A number of wooden staves of half a metre in length, accurately marked and divided, by a machine made expressly for that purpose, into decimetres, centimetres and milimetres, were distributed amongst the workmen; and although they would frequently by way of abbreviation, call a 'milimetre' a 'metre,' the misnomer did not lead to any errors. For the use of the pattern-makers, the measuring staves were divided so as to include an allowance for the contraction of the metal; that allowance never being left dependent upon the private judgment of the men. Besides, there was in existence, and accessible to the workmen on application to the foreman, *a complete system of distinctly marked and accurately executed internal and external gauges of various kinds*, so that any required measure could be tested, either directly, or by means of the calipers, if required."

It is more than probable that Sir Joseph Whitworth's pin and collar gauges have this origin. He was then a young mechanic of Manchester, and must have known of, if he did not see Mr. Bodmer's gauges.

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WORKS ADMINISTRATION.

Lectures before the Students of the Leland Stanford Junior University, Palo Alto, California.

BY J. RICHARDS.

No. 8. December 19th, 1895.

MACHINE TOOLS.

In the first part of the present lecture I propose to offer some criticisms upon modern machine-tool practice, especially standard machines for turning, planing, boring and drilling in metal work. This I feel at privilege to do, having been for many years connected with this branch of constructive work, both in metal and wood-working implements.

Reasons for such criticism will appear in the fact that in no other manner can your attention be so well directed to the subject, and because a knowledge of implements is an essential or even a qualifying part of one's administrative ability in a works.

I am aware that the present lecture may if published provoke a good deal of criticism, hence pains will be taken to follow the line of ascertainable facts in as many cases as possible, and in all cases to keep within features open to your own investigation.

Machine tools as a branch of constructive work is one of exceeding interest, because such implements are most nearly connected

with human effort and skill. They have in nearly all cases supplanted hand labor, and are directed to processes that not very long ago were carried on by manual effort, and are yet, as remarked, most nearly connected with the personality of workmen.

Since the earliest time when such implements, especially those for working in iron, became a branch of manufacture, or a separate trade, the best mechanics in all countries have devoted their skill to machine-tool making. This arose from a necessity for accurate work, and because unlike other implements they are the agents of their own production, create themselves, so to speak, and this is a very strange and exceptional matter, without a parallel in the whole field of skilled industry. Those who operate machine tools therefore understand their construction, merits and faults, which cannot be said of other implements, and this may be a reason for some of the peculiar features of the business to be pointed out.

In a wood working or textile manufactory, for example, the machines and implements do not appear in the same light. Those who use them are skilled in a totally different branch of work, and see only the functions of the machinery, besides there is not the opportunity for emulation and comparison between machines, because the machines of a class are not duplicates, or alike.

In machine work, intricate as it is, the machine processes are very few, consisting mainly in turning, planing, boring and drilling, calling for only three types of standard tools, while in wood working for example, there will be in comparison at least a dozen different standard machines. All these things constitute machine tool making an attractive and important branch of work, carried on, as before said, by the best mechanics in all countries.

From these circumstances we would naturally expect that this branch of work would long ago have settled down upon a scientific basis, attained uniformity, computed dimensions and strains, also measures of capacity and endurance, but this is not the case, and we find that one of the highest branches of constructive art, in so far as exact work and careful fitting, is carried on almost entirely without the aid of such information as it is the main object of your studies here to acquire.

It was not without some thought of this that the subject has been selected, and also with a belief that a great deal of good can be done by an attempt to bring machine tool making more within that class of structures that receive logical and analytical treatment the same as is bestowed upon hydraulic, steam and electrical apparatus.

To support what has been claimed in respect to machine tools, I will now proceed to note various facts in their development and in modern practice, which can be contrasted with other branches of machine work. In the first place attention may be called to the element of strain, which is commonly the foundation from which is computed the proportion of parts, and it may be asked, what you have met with in the various technical writings you have read relating to the strains in machine tools?

I do not include in the remark certain machines that endure direct strains; such as punching and shearing machines, but turning, planing, boring, drilling and milling machines, with the various modifications that may be classed under this head. Except an attempt some years ago at the John Hartmann Works, in Chemnitz, Saxony, to ascertain tool strain, that is, the cutting stress of certain tools, I have not seen any literature dealing with the strains in machine tools, neither of degree nor distribution.

It may be said in respect to the degree of strains, that these are variable and not easy to ascertain, and this is certainly true in respect to the actual force applied to cutting edges, but this is an inconstant and unnecessary element in such computations. The best measure for strains is found in the driving power, the tractive force of the driving bands, which falls within plain rules, and can be followed through a machine in a very simple manner in so far as degree.

Every machine tool is supposed to withstand the power that can be applied to its first movers or driving pulleys, and this is in fact a rule guessed at, and applied by tool makers, but not as in other cases by computation or any rules of general acceptance. Every machine tool is or should be made so it will not be wrecked in case of obstruction, and this condition must of course arise out of three factors, the strain or power of the first movers, the distribution of this force by gearing, and the momentum of running parts; the latter not being an element of much importance in machines for turning, planing, boring and drilling, or any machine wherein the tool stress is constant.

At the slow speed which the cutting action takes place, and the facilities for experiment, there are perhaps no other machines as a class in which the strains can be so easily computed or determined. For example, suppose that a bar is bolted to the face plate of a lathe, a weight hung thereon and the driving belt is shifted to the fast pulley, and the weight on the lever or bar is moved out or in to

balance the strain. The torsion on the spindle would at once appear. Such an experiment could be made on any small lathe in a few minutes' time. The thrust of a planing machine table or the thrust of a cutter bar in planing, slotting, and shaping machines, is still more simple, because falling in a direct line.

I mention these things, not as a suitable or necessary way of determining the cutting strain that machine tools should exert, but to show how simple a matter it would be to arrive at some rules in the case, without computation even. The direction and distribution of strains is a more complicated matter, but not very difficult compared to problems that are continually computed in other kinds of machinery. In a lathe for example, the lateral strains, those normal to the line of the spindles, fall at a very constant angle, or tangent from the work, downward on the front member or side of the main frame, and for the most part outside the main frame, in lathes that have their spindles set over the center.

The resultants of this strain, upward or opposite on the spindle supports, torsional on the main frame and so on, are easy to follow out, but it is not done by tool designers, and if it were there would soon arise some changes in their plans. For example, an investigation of these strains and their resistance by the various parts would never assign a position for a lathe spindle central over the bed or frame; neither would it indicate a lathe frame made like a ladder with two side members connected by cross girts, which is perhaps that form which more than any other permits torsion in proportion to the amount of material in a section.

Tool makers do not seem to care anything about such matters. It must be nearly twenty years ago when Professor John E. Sweet made models of girder frames of the cross girted and tubular forms, and published the results of his experiments, showing as now remembered that the same amount of material, would in resisting torsion be about four times as strong when disposed as a box or hollow section.

It is longer ago than that when he pointed out the absurdity of mounting long framed machine tools on four bearing points, when the foundations were not immovable, as no foundation is, he pointed out that a three-leg stool always stood firm, and one with four legs would not. No one disputed that, and I remember about the same time, when in the works of Messrs. Cope & Maxwell, at Cincinnati, Ohio, where a good many lathes were on the upper floors, the rear supports were unfastened and pieces of round iron inserted between

the frame and the support or leg so as to secure a central bearing. Mr. Maxwell informed me that if a heavy casting or other weight was placed on the floor near a lathe having four bearing points, the carriages would bind, by reason of the floor yielding, and the expedient named had to be adopted.

This matter never had much attention from machine tool makers, and as you may see they continue to provide the four bearing points the same as before. Had such an obvious improvement been proposed in steam, hydraulic, or other machinery, does anyone suppose that it would not have had instant investigation and adoption all over the world, in some form to avoid the unequal bearing of frames?

In European practice the effect of these twisting strains on high mounted machines is partially avoided in another way. The supports or legs of machines are inverted so to call it, made as pedestals with broad permanent attachments at the bottom, and a narrow bearing at the top, in other words the metal is disposed as an immovable vertical standard and to sustain weight, which is correct enough if we assume that the machines are to be set on immovable foundations, as is commonly the case there.

Professor Sweet is not the only one who has had the discomfort of seeing useful suggestion and improvement ignored by machine tool makers. I will name some more instances of an equally remarkable kind.

Messrs. William Sellers & Co., at least thirty years ago discarded the reversing train of wheels for planing machines, and applied two driving bands instead, one for the forward and the other for the backward movement, thereby saving a good deal in the cost of construction, avoiding noise and securing a better action in every way. They also made the bands narrower, moved them at a higher rate of speed, and so arranged the shifting apparatus that one band would be off before the other was on, so that one would not be pulling against the other, thus avoiding the screeching and loss of power that was inseparable from the old gearing. They also removed the feeding motions from the tappets that reversed the machines, so the feed could be controlled independently, and to avoid the severe strain that would otherwise fall on the tappets, with various other changes of much utility.

The useful results attained by these improvements were such that it might be said they created a new machine tool. It was the most original and sweeping departure in standard machine tools in their history for fifty years past. Had such a change been made

in any other kind of machinery it would have led to an immediate revolution, and gone all over the world as fast as descriptive literature would have conveyed the methods, but this was not the case with machine tool makers.

Some of these features after a time began to find their way out into the practice of this country. The two bands required about twenty years to become generally adopted. The separation of the feeding and reversing apparatus about the same time. The differential shifting apparatus has hardly yet become general in tool practice.

In England scarcely one of these improvements are yet understood or applied. Reversing is done by shifting a wide band three times its width across an idle intermediate pulley to reverse the tables. The feeding is done by the table tappets and acts at each motion of the table, whether the stroke be full or not. The forward and backward movements are fixed relatively, and cannot be changed after a machine is once made, and there is little or no understanding of Messers. Sellers & Co.'s improvements, made about thirty years ago.

Now, it may be asked, how is this possible? It is not difficult to explain. There is no science or even a literature of machine tools. No one knows or inquires into the movements and functions of planing machines. The makers keep on in a rut, making them over and over in the old way, until some purchaser demands a change.

Even at this day one may go into any of our machine tool works and ask for an analysis of these improvements made by Messrs. Sellers & Co., more than thirty years ago, and will receive but little information. The improvements may have been adopted, but not in the same way or for the same reason that like improvements are in steam engines.

In 1870, Mr. Baker, a well known engineer in Philadelphia, had some small engine lathes made to order there, and had the driving wheel on the poppet or wheel train spindle so arranged, that by simply sliding the wheel sidewise on the spindle, it would engage with either the spindle or the cone pulleys. The only change required for this was to make this wheel of the same pitch as the rear back gear wheels, and provide room on the spindle to slide the wheel, which would stay in either position without any fastening.

The cost of this was trifling, and no charge was made for the alteration which Mr. Baker estimated as adding about two dollars to the cost of making each lathe. The result of this improvement is

remarkable. The relative speed of the cone pulleys and the spindle of a lathe when back geared is about as five to one, so this shifting of the poppet spindle pinion changed the speed of the screw gearing in that proportion, so that in cutting screws of course pitch the wheel train was relieved of strain, that on the first mover being as one to five, or as the relative speed of the cones and spindle.

It is dangerous to the screw train of a common lathe to cut screws of coarse pitch, worm wheels and the like, indeed it cannot be done at all in many cases, and it is common to rig up some contrivance to connect the screw gearing with the back gearing when coarse pitch threads are to be made. Here is a simple little improvement not patented, of much value, and costing almost nothing at all, that has not, I believe, been adopted, even at the works where Mr. Baker's lathes were made, and only in one other shop, so far as I know.

About the same time Messrs. Harvey Bros., of Glasgow, began fitting their small lathes with a third pair of wheels in the back gearing. The result was such that a good many people who had previously purchased lathes from these works returned the lathes to be provided with this improvement. It adds fifty per cent. to the number of changes for speed, and avoids driving the cone pulleys at high speed when a lathe is back geared, also permits a much wider range of both speed and power.

This improvement was never patented, and has made its way into one shop in England and one in this country, so far as I know. Drawings and full explanations were published in technical journals and Messrs. Harvey's printed circulars.

Earlier than this, the same firm, and I think some others in England, quit applying back or multiplying gearing on the intermediate shafts of machine tools, and I will ask especial attention to this matter. It is one that more than any other will show the lack of analysis in machine tool making.

On a lathe the back gearing is placed on the spindle, so there is no torsional element between the gearing and the work, at least none that can yield much. In triple-geared lathes the second pinion is geared directly into the face plate, so even the spindle is relieved of torsional strain. No one thinks of any other method of gearing a lathe spindle, or that any other less rigid would answer, but as soon as we turn to drilling and boring machines there is a new arrangement altogether.

The two machines, lathes and those for drilling and boring, have much in common. They have spindles arranged to revolve at vari-

ous rates, subjected to torsional and lateral strains, and one would naturally look for a similar method of gearing, but this is not so, as you can see by referring to three fourths of the drilling and boring machines made in this country, and nearly all made in other countries.

The back gearing is not placed on the spindles, but on some driving shaft beyond, which becomes subject to the same or greater strain as the spindle, and thus the whole of the power at slow speed is transmitted through a pair of bevel wheels, liable to break, and causing a side thrust on the bearings inversely as the diameter of these wheels.

In radial drilling machines it is not unusual to find the back gearing placed on a third shaft, away from the spindle, interposing the torsion of ten to twenty feet of shafting between this gearing and the spindle, also through two, and sometimes three pairs of bevel wheels.

In common drilling machines it is almost an universal custom to place the back gearing on a second shaft, and transmit through a pair of bevel wheels, which answers for light drilling, but not very well for heavy drilling or for boring.

The faults of such an arrangement will become obvious if we imagine a lathe with its back gearing on the countershaft overhead, and a second shaft extending down to the lathe spindle, with two pair of bevel gear wheels to make the required angles. This would correspond to a common drilling machine, which is subjected to the same torsional strains as a lathe, and to the same or even greater strains in boring.

Now, it may be said, there must be some reason for this method of arranging drilling and boring machines, but there is none that I can discover, except a want of considering the strains, and proceeding in the same manner that other machinery is made. It seems to be simply movement in a rut, ignoring all but precedent and custom, and the proof of this lies in the fact that Messrs. Harvey Bros., of Glasgow, have not in many years made any heavy cutting machine not having the back gearing on its spindle, but we need not go to Glasgow for precedents. Messrs. William Sellers & Co., of Philadelphia, have not I think in fifteen years past made a drilling machine in any other manner, and in Prof. Smith's office you will find a drawing of a radial drilling machine, the most difficult of all to arrange in this manner, with the back gearing placed on the spindle. It is a fine example of logical and scientific design, that

you will do well to examine, as it will relieve me of some of the onus of criticising my fellow machine-tool makers.

I could go on through planing, shaping and other machines, pointing out features of unscientific design, but think enough has been presented to show that there is a marked want of what we may call logical design in machine tools, and the improvements when made are not understood and are avoided as long as possible.

This remark applies especially to European countries, although it must be admitted that there is in Germany indications of investigation and change in machine-tool practice and the application of methods that have so much advanced many other branches of skilled manufacture there.

In this country Prof. John E. Sweet has with his usual candor written a good deal upon machine tool making, and is almost alone in being able to look at the subject generally, and not alone from the particular practice around him. His qualification in this branch of work is sufficiently indicated by the fact that he was appointed a judge of the machine-tool exhibits at the Chicago Exhibition of 1893.

Prof. Sweet, who when he does a thing, does it as well as he can, and, as I have been informed, spent a good deal of time, amounting to several months, in preparing a report on machine tools at the Exhibition. He examined over four hundred machines, and is said to have prepared descriptions and criticisms of more than three hundred different machine tools. What an invaluable addition this report would be to our technical literature and to the industrial interests of this country, especially to machine tool makers, but I fear it is lost to the world, and will never see the light. The reasons are no doubt wholly inconsistent with the future good of the art.

It is not the purpose of these remarks to draw invidious comparisons, or to disparage the general improvement made in standard machine tools during fifty years past, much less to deny that special machine tools have been as progressive in design as many other classes of machinery, but to point out fairly that general practice in the former has not been progressive in the degree that applies to most other kinds of skilled industry, and especially to point out that in equipping a works one should look beyond the average trade circulars and claims of advertising matter.

If, for example, a maker of engine lathes says that a pair of metallic clutches on the countershaft are a necessary and commendable feature of his lathes, it is perfectly proper to consider whether

a shifting band is not the most perfect friction clutch ever devised, and if the bands were narrow and their speed sufficient, why the control is not as complete as is possible with a metallic clutch; also if the mechanism to reverse a planing machine continually, is not equally suitable to reverse a lathe only one time in a hundred compared to a planing machine? Such investigation can do no harm, and would if followed up by those who purchase tools soon modify and improve many things evidently faulty in existing practice.

PATTERN MAKING.

The term pattern employed in machine work is not quite relevant, as it conveys an idea of configuration in one plane. "Model" is a better term, and is employed to some extent in English, as it is in French and German. Pattern is, however, the name in use here, and will be adopted for that reason. In a works it is a department that requires a good deal of administrative attention, because more than anything else admits of wide divergence in cost and quality.

Patterns are commonly considered to be an expense, not because of their nature and relations so much as their variable cost, which arises out of two opposite circumstances: the frequency of use and the infrequency of their use.

If a pattern is employed in making ten castings its cost should properly be apportioned between ten castings, one tenth being charged to each, but the number of times a pattern is required is not often known when it is made, so the whole cost is charged to the first casting, and its subsequent use goes to profit or a diminished price for the castings.

If a pattern is provided for use one time, or a special pattern, it is called, it is made in the cheapest manner. A pattern for the same thing may cost ten dollars or fifty dollars, as it is made for standard or special use. It can be nailed up without fillets, the corners left sharp, and unpainted or unvarnished, leaving a good deal for the moulder to "dig out," as it is called, or it may be a fine finished piece of wood work, filleted, cornered and varnished. In some cases a pattern is no more than a "strike" or sweep, a thin piece of wood or metal to scrape or strike the contour of a mould, then again a pattern may not be a model at all, but to form an envelope or matrix of clay and sand, improperly called a core, that constitutes the mould itself.

By this time you will have concluded, no doubt, that a machine pattern is a very indefinite kind of thing, which is true, and at the

same time will perceive what a range of discretion must be accorded to a pattern maker, who, unless instructed, has to consider all these matters himself, and so determine the form and quality of each pattern prepared.

Pattern making is commonly claimed to be the highest branch of skilled work carried on in a machine works, and it is if we assume that each pattern maker knows how to construct all kinds of patterns and adapt them to the circumstances of each case. Pattern making requires a complete knowledge of drawings, that is, how to interpret and make them, because pattern makers have to reproduce drawings for castings, so as to add for shrinkage and allow for the finished dimensions.

A pattern maker must of course understand moulding, so as to adapt his patterns to these processes. He is responsible for means of setting and supporting cores, the method of moulding, that is, partings, venting, and so on. He must also understand the amount required for finishing, which is by no means uniform. The cores will swell and the castings will shrink, so there are allowances and conditions of many kinds to be taken into account, and besides all this the work itself is of a kind that demands much skill in the use of tools.

Patterns when finished with transparent varnish, shellac being the common coating, must be made as carefully as cabinet ware, because every joint shows much plainer than if the wood was bare, but when the varnish is colored with lampblack it is opaque, and hides the wood work.

The conventional method was formerly to varnish patterns with clear shellac, and the cores with black varnish, but this custom has nearly gone out. It is expensive and useless, adding a great deal to the cost of patterns by reason of the better and often useless work required. I remember having introduced this revolutionary change in a works at Philadelphia many years ago, by reversing the method of varnishing. The pattern maker thought his shop disgraced, but on coming to this Coast I found the same method in use here.

Pattern making is in San Francisco one of the most advanced processes in machine work, a matter easy to account for. In the first place nearly all the patterns are special, and not used for a long time, as in the organized and classified work done in the East, consequently a good many more are required. They are regarded as an expense, and so treated in the accounts of many of the works, hence there is a continual effort to cheapen and avoid this expense. Pat-

tern makers come here from various countries, bringing with them and applying all the expedients they have picked up in former experience.

Moulding is well done as to methods and to the soundness of castings, but badly done in respect to smoothness. There are as many different ways of moulding a piece as there are ways of making a pattern. It may be sound, true and smooth, or the opposite of these. In fact, but little can be said or written in respect to either pattern making or moulding that will come under the head of rules. Both things are intensely technical in nature, and have to be absorbed by contact, so to speak.

A pattern shop requires all the light that can be attained, the more the better, and a great deal of room. Each workman should have 150 square feet of bench room, and as much machine room, in order to work free on miscellaneous work.

The employment of machinery in pattern making presents great difficulty when compared with other kinds of wood work. The extent to which machines can supplant hand work is dependent upon duplication, and as no two patterns are alike, this greatly restricts machine processes, still a great deal of expense can be saved in addition to planing and sawing, which are always provided for.

One important machine extensively employed in Europe is for dimension sawing. Its functions are to saw either way, parallel with or across the grain, to finished dimensions, more accurate than pieces can be planed by hand, and smooth enough to sand paper and varnish on the sawn surfaces.

These machines were made for at least a dozen years by the original inventor before any one had the courage to imitate them, and are one of the highest types of wood-cutting machines ever made by any one, and if excelled at all in accuracy it is by other machines by the same maker, Baxter D. Whitney, of Winchendon, Mass. He supplies more of these machines abroad than in this country, at one time a great many more, and they are better known in England than here. There is but one of them on this Coast, and that has by neglect, and the difficulty of dressing the saws, been reduced to a plain sawing machine.

They are provided with two saws, one to cut across and the other with the grain. These saws have no set, being ground tapering from the teeth inward, so they plane as well as saw, and when in perfect adjustment will cut out a perfect circle of any number of sectors, or any number of cubes, that will build up and make a solid;

cut grooves, rebates, mitre, and all such work, and effect quite a saving in a pattern shop. Core-box machines for cylindrical work have made a good deal of progress, and are now recommendable machines; so also jointing machines. The standard machines are a common saw-bench, band-sawing machine, shear and face lathes.

The many ingenious methods of producing forms in cast iron by the use of patterns is one of the most interesting studies connected with the construction of machines and iron work. Sometimes the patterns when inspected give hardly a clue to the form of the casting they are to produce, especially if the work is made in or by cores.

Iron castings, as you are no doubt aware, are made in different kinds of moulds, known as green sand, fired or dried moulds, and loam work, the quality and cost of moulding being in the order named. Sand is used because of its porosity permitting the escape of gases in every direction through the mould, and the amount of vapor and gas that results from the hot iron running into the mould, is as the moisture and combustible material contained in the sand.

Moisture must be added to produce an adhesive condition of the material, and in green sand, that is with undried moulds, the vapor and gas is excessive and liable to disturb and spoil a casting while fluid, if there is not sufficient vent provided by the porosity of the mould, and by minute holes made with a pointed wire called a vent rod.

Fired or dried moulds are made of green sand, partially dried on their interior by fires built in the moulds, so as to dry out the moisture, and thus prevent the generation of vapor in casting. It is a common process for all large castings.

Loam moulding is the highest branch of the art, and in general terms means preparing moulds without a pattern, of a material more tenacious than a common sand mould. Such moulds are built from drawings with the aid of "strikes" and like implements. A man may be a good moulder, as the name goes, without any knowledge of loam moulding.

Such moulds are thoroughly dried by firing, or are baked when it is possible to do so, that is, when the whole mould can be dried throughout. Being dry there is not much vapor, the moulds are strong enough to prevent swelling or distortion, and the iron is not chilled when poured in.

There is always an economic problem as to where green sand casting should stop and loam moulding begin. Against the greater

expense of loam castings there must be placed the expense of patterns and the better quality of the castings, and especially the avoidance of inherent strains. In the Industrial Works, at Philadelphia, when Mr. Dougherty, of the old firm of Bement & Dougherty, had charge of the foundry work, nearly all the machine frames were made in loam moulds. He was perhaps the most skilled moulder in this country, a well educated man with experience in several countries. He was at one time a manager in the Royal Foundry, at München, Bavaria. He was a poor boy, raised at Columbia, Pennsylvania. When he went to Philadelphia, he walked barefoot to save his shoes. He is yet living, a patriarch among foundrymen, retiring from business in 1872.

These remarks on pattern making and moulding are introduced here, not for instruction in these arts, but to indicate in a brief way some of the intricate problems that arise in the management of a works. Workmen, or even a foreman, may not have a direct interest in the manner of preparing patterns or moulds, and a manager should have at least general knowledge of all these matters. Both these things enter into estimates, forming a portion of the components of cost, to be made up, not from accomplished work, but for work to be done. It is true that both patterns and moulding may be included in a general price of castings, and are frequently disposed of in this manner, but this will not answer at all in many cases.

I will close this lecture with some remarks on the relation between hand and machine processes, because it is in forging, pattern making and moulding, that these relations are most apparent, and those in which we can best trace the limitations of machine action.

The functions of machines can be set forth in the two following propositions:

Machine action in the conversion of material is confined to true geometric lines.

Machine action in the conversion of material is by repetition and duplication.

In respect to the first proposition it is easy to observe that all forms of wood, metal, or other material, can be cut away and shaped by machines when the contour is regular, that is, flat, straight,

angular or curved, in lines that admit of guidance. All kinds of circular and true elliptical forms can be turned; straight lines can be sawed and planed, also angular and curved ones if regular; so it is easy to see how a desk can be made by machinery, but a common stove cannot be so made. A pattern for a flange can be turned, but one for a faucet must be cut out by hand.

Iron not having a grain or lamination like wood, can be disposed in almost any form, and as models or patterns made of wood are like the iron to be produced, it disposes the wood without much respect to its fibre, and as the castings do not as a rule require finishing, except in certain places, there is no need of a regular contour, so every circumstance tends to limit machine action in making wooden patterns for castings.

The same is true to a greater extent of forgings. There is no regularity of contour in work, except surfaces to be finished, and not in all of these, so that aside from plastic or what we may call flowing treatment, machines cannot accomplish much in forging, because the lines are not true or geometrical. A smith may work all day and not strike two blows that are precisely alike in effect. Each blow calls for a separate exercise of intelligence.

It is the second proposition, however, that has most to do with machine limitation, that of duplication. This is an economic limitation. If there is but one, or only a few articles to be made, the adaptation of machines for the work is out of the question, no matter how much might be gained in effect. If there are thousands of an article to make, no matter what it may cost, machines can be prepared for the work. I have been informed that the first Waterbury watch cost $15,000 and the thousandth one cost $2.50, which is probably correct.

It takes twenty to thirty minutes to make a horse-shoe by hand, and only two seconds by machinery, but if a man has only one hundred such shoes to make, or even a thousand, he could not afford to provide machines for the purpose.

It is therefore in extensive duplication that machinery becomes possible. The actions of a machine must in the nature of things be a succession and uniform.

Finally, I will say that there is no more interesting subject to consider, and perhaps not many more useful to observe, than the distinctions and relations between hand and machine action in the conversion of material.

9

WORKS ADMINISTRATION.

Lectures before the Students of the Leland Stanford Junior University, Palo Alto, California.

BY J. RICHARDS.

No. 9. January 16th, 1896.

The present lecture will be directed to two different topics, invention and the element of coöperation in works.

It has been found exceedingly difficult to correlate the various topics that can be included under the head assumed for these lectures, but there is this excuse. Such fault of diversity here is not a circumstance to what will arise in practical administration, and some foretaste of this fact may not after all be out of place.

To dispose of an oil agent, a shop row, a charity solicitor, a questionable casting, compute the capacity of a water pipe, order in stock, and check off the dimensions on a drawing, all within thirty minutes' time, is discursive, also is, unfortunately, a fact of management.

INVENTION.

Under this head may come the various efforts to improve processes, and products also, the addition of new ones, and it is a matter of astonishment when we come to think how comprehensive the term is, especially in its original and wider meaning.

At the present day, in this country at least, invention is employed to designate discovery, and also by some people to define a kind of peculiar faculty that is peculiar to certain persons, or possessed in a varying degree by different people, a meaning that finds warrant in the terms of the statute and in various decisions of the Federal Courts.

The word comes from Latin *in* and *venire*, to come in, or freely translated, to bring in, and this is practically the meaning imparted to the term in England at this time, because an inventor there is one who "brings in" either by his own efforts and production or by importation from abroad, is in short a person who gives to the citizens of the country a new improvement.

As the subject of patents on inventions will have some interest, and perhaps be of use in future, I will give some space to it here. Our own patent system, about a century old, like the patent laws in most other countries, had its origin in the British Statute of Monopolies, enacted in 1623, two hundred and seventy years ago. It is commonly spoken of as the Statute of Monopolies, but it really was a statute to prevent monopolies, because previous to that time it had been a custom of the Crown to grant patents of monopoly for certain trades irrespective of invention, thus taking away from the public what they already possessed and giving it to one person or a company.

The statute of 1623 connected invention with such grants, that is, a person to have a monopoly must invent or bring in a new thing not before known to the public or possessed by them, so no harm could be done to any existing right or interest by reason of the monopoly.

This old law is yet in force, and, as said, is a kind of basis on which rests nearly all the patent laws of our time. It consists of only thirteen lines, as follows:

"Provided that any delaration before mentioned shall not extend "to any Letters Patent and grants of privilege for the term of four- "teen years or under hereafter to be made of the sole working or mak- "ing of any manner of new manufactures within this realm to the "true and first inventor and inventors of such manufactures, which "others at the time of making such Letters Patent and grants shall "not use, so as also they be not contrary to the law nor mischevious "to the State, by raising prices of commodities at home, or hurt of "trade, or generally inconvenient, the said fourteen years to be "accounted from the date of the first Letters Patent or grants of "such privilege to be hereafter made, but that the same shall be of "such force as they should be if this Act had never been made, and "of none other."

As a further matter of curiosity I have brought, and will leave with Prof. Smith for your inspection, a patent on hydraulic apparatus, granted under this old law in 1642, two hundred and fifty-four years ago. The patent was first issued in Holland, and then in England to Mr. William Wheeler, as an importation, or as it is called now, a "communication from abroad."

The modern acceptance of a patent for invention is that of a contract between the inventor and the public, wherein he agrees at the end of a certain time to transfer to them a new and useful discovery, furnishing an accurate description of how to make and use the invention. He to have as a consideration on the other part, the exclusive use of his new creation for a term of years. Letters Patent are considered an act of grace instead of right, this idea coming down from the old statute quoted.

The idea of an inventive faculty, or a peculiar function of the mind exercised in invention, arises, no doubt, from a fact that, so far as I know, has not been treated upon in any writings on the subject, namely: There can be no inherent or natural right to a new invention or discovery that is not personal to the inventor, in other words cannot be obtained except through him. If such new invention be the result of inductive or deductive reasoning, the application of skill, mathematics or other means common to skilled persons, then there cannot exist a personal right. But if, on the contrary, invention be a faculty personal to the inventor, then he may acquire a personal right to his invention. It will not be necessary to pursue this matter further, it might lead us into the department of law, where mathematics and exact things are not very favorably received.

I will venture to qualify the term as meaning a habit of mind associated with skill, observation and reasoning power, that enables people to make new and original improvements in implements, processes and products, such habit of mind being more or less marked in different people, just as other traits are.

In a works such improvements come from all sources, from owners, managers and workmen, and from various incentives. Very often from a love of novelty, or a habit of mind that may be called curiosity; sometimes by accident, or even from laziness, as we are informed in the case of inventing automatic valve gear for steam engines. It may also come from emulative objects and gain, but I am inclined to think most often from the discovery of a want or a fault which the inventor sets out in a methodical way to supply or remove.

This may be called the first step in legitimate and useful invention, the discovery of a want or the lack of something useful that does not exist. It cannot be denied that useful invention is sometimes a result of discovery, especially in the field of chemistry, which is mainly an experimental science, but at this day not often in the mechanic arts, except in the pursuit of a definite object. This should be explained to apprentice draughtsmen, who more than any one else are exposed to the wiles of invention. Designing is to them the same thing as inventing, because the powers or faculties brought into play in preparing designs is to the beginner a mystery. He cannot distinguish between what is new and what is old, and commonly cannot judge of the results, so as to distinguish between the curious and useful.

In a works there is continual difficulty on the part of a manager to dispose of new propositions of one kind or another that are sure to come up, and a good deal of such trouble can be saved by the application of some rule which every one can understand, for example:

Any new improvement to have direct commercial value should produce the same thing for less money, or a better thing for the same money. This rule is almost an invariable one in respect to all minor improvements, especially in products.

Another rule is that the commercial value of all improvements is as the breadth of their use. This is also a good rule, one that is too often overlooked. An improvement in engine valves is likely to be of more value than an improvement in indicators, because there are a great many valves to each indicator. An improvement in transits is more important than one in theodolites, because more of the former are employed.

A third rule is that the chances of improving anything depends on the amount of research and ability that has already been applied to the same thing. This is also an important rule that would save thousands, if not millions, of dollars each year if applied to the efforts wasted by those incompetent to deal with subjects undertaken.

At this time there are a great many contrivers at work inventing and improving impulse steam engines who are wholly ignorant of the thermal and dynamic problems that are involved, and either ignorant of or ignoring the fact that men of the highest scientific attainments and skill have been devoting their best and in some cases exclusive efforts to the improvement of such engines.

The Hon. C. A. Parsons, of England, for one, has in his first engine, and all important changes that have since been made, laid down by computations made in advance what the results should be, and has come very near in each case predicting such results with wonderful precision.

As these engines present an especially suitable illustration of the subject being considered I will follow them farther and attempt a kind of analysis of invention as applied to them. Impulse engines present four conditions subject to improvement. First, the thermal problems involved; second, the laws that govern the qualities or behavior of elastic gases; third, the dynamics of flow, or impact and reaction; fourth, mechanical contrivances and devices or agents to control and utilize the three first-named conditions.

Now it is evident that the machinery or mechanical devices come in the order named, the last of all, because such devices are only an agent of transmission, and of no use whatever unless the thermal, physical and dynamical conditions are not all included. These are the generic features, so to speak, and it is to these attention must first be directed in order to make any considerable improvement in impulse engines. This term "impulse" is not wholly relevant, but we have no better word among the hundred thousand in our redundant language, hence is adopted here.

It will be wrong to claim that mechanical contrivance is not an important, and in a sense an independent element in such engines, involving, as it does, strains on material never before to be dealt with, and velocities that have no parallel in machine practice, but what I want to make plain is that to begin by contriving mechanism is commencing at the wrong end of the cycle, and is not of itself likely to add anything of value in the art.

The same rule applies in a varying degree to all kinds of invention. A locksmith or a clockmaker may improve a steam engine, but the chances are that he will not do so in any permanent manner. I have neglected the rule of sequence first laid down in going on to discuss the third rule instead of the first one, and must now go back.

Any invention or improvement to have commercial value should produce the same thing for less money, or a better thing for the same money. This is intensely commercial, repulsively so indeed, but it is unfortunately a fact, one that stands in the path of progress. It is the chief point of attack by advanced mechanics and engineers, whose spirits and efforts are in the line of a better thing for more price. Both are legitimate, and are in a sense the same thing in

nature, but subject to very different commercial conditions.

Buyers are not logical. If they were there would be no advertisements appealing to credulity, as will be shown in the next lecture. Their idea is that all invention and improvements of every kind should come under the rule first named. There is also the fact, and it is a very important one, that the amount one can purchase is inversely as the price.

A person starting a small machine shop with a small amount of capital should not purchase a very fine engine lathe when he could for the same price buy two cheaper lathes of a serviceable kind, so the matter is not one of sentiment alone, and it should be the aim of a manager as far as possible to increase profits by improvements in implements and processes, instead of raising the price of products, an injunction, however, not needed just at this time.

The second rule, that invention and improvement have value as the extent of use, contains a very useful suggestion, in that efforts to invent and improve should be directed as much as possible to things produced in large quantities and to processes extensively carried on. An invention in stop valves is more important than one in surface plates, as five hundred to one, no doubt, but inventors are very apt to overlook this, or at least not take it into account.

Out of the same rule comes a further one in respect to the stability of trade, which is apt to be as the breadth of use or as the volume of product, an economic point that has much to do with plans for founding a business. A cent a yard on plain cotton cloth is more apt to return a profit than a dollar a yard on fine woolen cloth, because the product in volume will be for the cheaper cloth greater than a hundred to one, but there is more than profits to consider in this term of stability. There is the constancy of product.

This is well illustrated in the case of manufactures in Great Britain compared to this country. They have a population of but little more than half as many people, but their environment furnishes a market around them of 400,000,000, while our market does not include more than one fourth this number of people. Their exports in 1891 were $2,128,000,000, and ours, $825,000,000. The result is that their diversified market or the breadth of use, it may be called, prevents quick and excessive fluctuations in trade.

In 1885 I went out from here to England in the midst of the business depression of that year, and was told it was the same in England. I found the works in the East, many of them, closed, some operating half time, a good many one fourth time, notably the American Standard Gauge Works, described in the last lecture,

operating but one day in each week. On reaching England, where I was well acquainted and understood the circumstances, I found no discernable difference in the volume of work, and two thousand men out on a strike at New Castle, but people were complaining there just as much over a shrinkage of ten per cent. as they were in this country over one of fifty per cent.

Inventions and improvements are therefore of commercial value in proportion to the breadth and diversity of use, a very important thing to keep in mind as a matter of business policy.

What may be called legitimate invention of devices, such as should be encouraged among draughtsmen and workmen, is a result of analysis. I will attempt to illustrate this by a familiar example, that of stop valves for fluids. In common practice these consist for the larger sizes of a wedge or a pair of dies sliding between two faces or seats of non-corrosive metal, capable of stopping flow in both directions, absolutely tight when closed, and leaving a straight through flow when open. Such valves are worth about $4.00 per inch of diameter, from three to six inches bore, and are as you know a familiar and extensive article of manufacture and commerce.

Here in California, where a great deal of land is irrigated from pipes, there are vertical outlet hydrants, spaced so as to flow the water all over the land by means of training ditches. A farmer sometimes requires a great many stop valves for these hydrants or outlet pipes, frequently hundreds, and to provide the standard fittings would be an expensive matter.

Here then is a want not completely filled in a commercial sense, and a chance for invention. To set about this by contriving mechanism is not the best way to succeed any more than in the case of the impulse steam engine. The proper way is to first ascertain the various functions of standard stop valves, and see what of these can be omitted for irrigating purposes. These functions, most of which have been named, are: (1), resistance to high pressure; (2), acting on both sides or in both directions; (3), noncorrosive surfaces; (4), straight flow when open; (5), absolute tightness when closed; (6), wearing endurance in use.

In an irrigating valve there is no need of closing but in one direction, there is rarely much pressure to be resisted, corrosive action can be provided for with a sheet of leather or celluloid, straight flow is not required, absolute tightness is not essential, endurance is almost avoided by infrequent use and renewal of valve faces.

Here it will seem that we have the whole valve eliminated, but

not so. There remains capacity to sustain low pressure, closing the water passage in one direction, reasonable tightness against leakage, endurance against infrequent use and a substitute for the noncorrosive metal. This much remains and these are the elements of the new valve.

There remains now the flesh to be put on this skeleton. The subject is ready for the contriver or the constructor, who will adapt to these conditions the operative elements, but he must also begin in a systematic manner, something as follows:

First a socket to receive the vertical pipe, continue this socket above the pipe as a nipple, and face the end for a valve seat, and surround this on four sides with a spout to catch the water and deliver it at one side. The depth of the spout should be enough to permit a cross bar or cover on the top, through which passes a screw to force down a plate or valve on the top of the discharge nipple. The screw nut to be cheap, and to prevent corrosion, can be cast around the screw of some alloy. Such a valve, which will cost about one dollar per inch of diameter, will be just as good for the purpose as one that will cost four dollars an inch.

This has been done, but not I suspect in the manner indicated, nor as well as it might be done in that way, but by an opposite course, beginning at the last end, that is, by contriving and a course of backward evolution that might have been saved. These valves are made in the southern end of this State at about one third the cost of the standard kind, and might be much cheaper still by improving the methods of construction.

CO-OPERATION IN A WORKS.

In what may be called human economy all changes, and especially those of an ethical kind, move slowly in a course of evolution that if carefully observed may give a very certain clue to the future.

One of these features of our time pointing to some great change in the future is association for economic ends, as distinguished from combinations for security to maintain a faith or a form of government. These economical or internal associations, among which are trusts, commercial combinations and the great labor unions, have their rise or inception in the inequalities of government, methods of taxation and privileges not of general attainment. Happily we are not called upon in the present case to consider this subject beyond its unit, so to speak, the small associations founded in industrial establishments, such as management at this day is always called upon to deal with.

This country at this time has less of such associations than any other in the world where large industries are carried on, but the method is rapidly extending, and is found in some form in nearly all of our large works, relating to insurance, relief, instruction, medical attendance, entertainment and so on. It is an important feature, one that exercises much influnence and, as I believe, deserves encouragement.

These shop associations are older and, as remarked, more common in European countries than here, and have become permanent in some phases not yet successfully introduced here, in commercial trading for one thing, which in England is a very important matter. I am not aware of what portion of the supplies purchased is from coöperative stores there, but am quite sure it is more than one half of the whole consumed by the skilled portion of the population.

The idea of coöperative supply stores began in Rochdale, a surburb of Manchester, about thirty years ago, and had the encouragement of John Bright, whose name has been so prominently connected with humane and useful enterprises that have tended to the betterment of human conditions, not only in the industrial world, but in opposition to slavery, vice and whatever was undesirble in a community. The store in Rochdale was so managed that food, clothing, fuel, medicines and so on, reached the consumer at a small advance on the wholesale prices.

The system has extended to enormous proportions. The army, navy and civil service have such stores, but not operated with such advantage as the original one at Rochdale, which was instituted by the people of a single factory. In some cases the purchase of goods by firms to be distributed among the workmen has been tried, but this leads to a kind of paternalism that is offensive to the better class of workmen, and like profit sharing has no quality of permanence.

One of the most noted examples of coöperation among the people of a works is in Ireland, at Bessbrook, on the Newry Rriver, in the County Down, a spinning town of five or six thousand people, where everything down to the municipal government is on the coöperative plan. This is a most remarkable place, one of the most orderly known in the whole world. It was here where the first electric railway in the United Kingdom, and almost the first in Europe, was built, a line six miles long to the town of Newry, where the electric current was generated by water power. No liquor is sold, and there are no policemen in Bessbrook, at least none in commission, the owners of the works, a Quaker family named Richardson,

assuming this executive function and appointing deputies without service so as to comply with the requirements of the law. Here almost every want is provided by coöperative effort among the workmen and owners, acting under rules of a democratic nature, and the result, after a long experience of at least fifty years, has proved successful in every way.

Saltaire, in England. another example of coöperative works, organized by Sir Titus Salt, who founded not only a novel community, but a new manufacture of much importance, that of making cloth from the hair of the alpaca goat or llama of Peru, a material that had but little value or use previous to this manufacture. I am not aware of the particulars of this extensive and successful establishment, firmly founded at least thirty years ago. As however, the present subject is the element of coöperative association in works, and what it may have to do with administration, I will take an example and describe the methods as well as possible, not completely of course, because a mere visitor to a works cannot acquire complete knowledge of such things.

The example will be the Cornwall Iron Works of Messrs. Tangye Bros., Birmingham, England, where at the time of my last visit there were employed about 2,000 men. These works are almost on the site of the old establishment of Boulton & Watt, where James Watt made his first successful steam engines, and where the firm of James Watt & Co. did business down to the past year, when the firm was absorbed by the Cornwall Iron Works. The firm of Tangye Bros. consisted of four members, the youngest, Mr. George Tangye, being the general manager, and I doubt if any one in such a charge has given more careful attention to the subject of administration, or has succeeded in a greater degree in such management.

Thirty years ago Messrs. Tangye Bros. were paying a rent of $150 a year for power and premises in Birmingham, making screw bolts and other rough tackle, now they have about 3,000 men. An accident brought them in contact with Richard Dudgeon, of New York, the inventor of the hydraulic jack, who entrusted the manufacture of that implement in England to these energetic young men, and this gave them a start in a singular manner.

The *Great Eastern* was then being built by Scott, Russell and Brunel, at Deptford, in London, parallel to the Thames, to be launched sidewise, as is now the custom in some of our lake shipyards. Her enormous size and weight of 28,000 tons had no precedent, and the launch was a failure, so were numerous attempts to

get the vessel off, until Messrs. Tangye Bros. thought of pushing her in with their little hydraulic jacks. Train loads of these were sent up to London, and a whole forest of them set beneath the great ship and she was pushed into the water at low tide. This caused much astonishment, and was the start of the firm, which in 1880 had 2,000 men employed.

The workmen, and indeed the whole force, including the owners, are organized for coöperation in various ways. There are lecture rooms, libraries, schools, medical men employed by the year, Sunday schools, funds for accidents, sickness, insurance, trading, and indeed nearly all that enters into the economy of living.

The members of the firm contribute their quota, and the works also. The owners meet the men on holidays and when there is any occasion of importance, and it is Mr. George Tangye's custom to go over from Heathfield, two miles away, to attend the Lyceum or other meetings of the workmen every week when he is at home. At my last visit to these works I had the pleasure of going through with Mr. Tangye, the manager, and it afforded a lesson never to be forgotten, and one that may be of some use if described here.

He wore a suit of tweed that would cost about five dollars of our money, and was dressed no better, or as well, as the draughtsmen and clerks, and seemed to assume no more authority. Our trip was continually interrupted by Mr. Tangye calling out to the workmen to ask about some one who was ill or had been injured. He seemed to know every man in the place, and could call them by name, also knew everything that was going on.

We finally reached the boiler-making shop, where a man was calking seams with a pneumatic machine suspended from the ceiling and resting against the workman's breast. Mr. Tangye watched the man a moment, then went to him and said: "Tom, give me that thing a moment." He set the machine, and turned on the air for a short time, and then said: "Take that apparatus down and send it around to the tool department for improvement. No man should use a tool like that, the jar will injure him."

"How can you remember all these things, and keep the run of all these men and their work?" I asked. "System and coöperative effort," said he. "There are now finished and in process, including steam pumps, fifteen hundred steam engines in the works, and all this causes me less trouble than five such steam engines did ten years ago."

We went to the steam engine factory, as it is called, and it certainly deserved the name. In the assembling room were cases

containing piles of cross heads, pistons, valves, glands, cranks, connections, and all the elements of the commercial sizes of steam engines of a very high class, all made to gauges and interchangeable. Men were assembling engines which passed in regular order through the various successive stages of trying, painting and packing. It was a manufacture certainly. At 12 o'clock we went to luncheon in a large dining room, where all the office force met, foremen, draughtsmen and clerks, also the owners and guests. Mr. Tangye took the head of the table, and directed his conversation to various members of his staff and others. They all discussed the affairs of the works. It was a council meeting of the Cornwall Iron Works, and a very important element in its management. Social distinctions, however marked outside, were eliminated here; all stood on a common coöperative level to consider and promote the good of the business.

All the work is done on the contract system, before described in these lectures, Mr. Tangye remarking that not even a screw-bolt was made in the Cornwall works by time pay.

This system of a free mid-day meal, served in the works by the owners, is common in England, and it seems to me is one that should be carried out in all large works of an engineering nature in every country.

It is also common in England for the owners to provide a dining hall or room for the men where they can warm and eat their dinners, read the papers, smoke and hold their meetings. I know of one works where a cooking range that cost $400, and a piano that cost the same amount were given to the men as equipment in their hall. Twenty-three periodicals were subscribed for in this case by the men and the owners.

Coöperation is actual and complete under such circumstances, and I have explained a principal reason that England with a working week of fifty-four hours, can pay to her workmen nearly double the wages of Continental Europe, and successfully compete in the markets of the world.

The workmen there are under the most favorable conditions that exist in the whole world, and this they very well know. Twenty-four hours will take them to France, Germany or Belgium, and six days to our Atlantic ports. They know well the rate of wages and the conditions of their trade in all countries, but no good workman goes away. The coöperative spirit makes them feel at home, and that they, like the owners, are directly interested in the works.

10

WORKS ADMINISTRATION.

Lectures before the Students of the Leland Stanford Junior University, Palo Alto, California.

BY J. RICHARDS.

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In the present lecture, and last of the series, I will present some views upon an element in the administration of works not hitherto mentioned, a very important one; that of the means employed to sell the product, especially by advertising and publishing circulars, or, as we commonly but incorrectly say, catalogues.

As usual there will be a good deal of fault to find, and I will remark here, as should have been done in the first instead of the last one of these lectures, that this fault finding is not agreeable or without design. Adulation destroys emulation, and is a stumbling block to progress. If some one informs you that your methods are perfect and the best in the world, there is no reason for changing or even thinking over the matter, but an adverse criticism, while it may not promote the personal popularity of a lecturer, sets you at work, arouses emulation, resentment, or some kind of thinking, and all kinds of thinking is good. All kinds of criticism will be cheerfully borne if you grant me candor and a desire to arrive at the truth.

The English and American people are especial sinners in this matter of advertising, and their methods are in many cases a reflection on the common sense of purchasers or the people addressed, a fact that a good many years of observation have failed to explain or find any logical reason for.

The Anglo-Saxon people are commonly credited with what we call "hard sense," and in such matter-of-fact things as the products of skilled industry it seems strange to see appeals to impulse instead of judgment, but an examination of advertising matter in this country and in England must lead to the conclusion that impulse and credulity are the faculties to be appealed to.

I am not in this opinion setting up my own views. In fact one in such an environment, and himself a transgressor, is not apt to criticise or perceive faults of the kind. My attention was particularly drawn to advertising methods about sixteen years ago, when in company with a prominent Swedish manufacturer, who had never been in England, we arrived at Victoria Station in London. My friend was in amazement. The interior of the station, waiting rooms, and indeed all available places, were covered with advertisements, some of them large paintings of much beauty and artistic merit, similar to those seen in the mole station at Oakland, but more elaborate and expensive.

The Swedish gentleman glanced around and was astonished. He had never seen anything of the kind in a railway station, and was non-plussed. "Who furnishes all these pictures?" he asked in Swedish, and on being informed of their purpose, said: "these people must sell their goods very dear to afford so much expense," and then followed a number of questions, some of them unanswered to this day. I will repeat some of these questions as well as can be remembered. "Do people buy goods because of these pictures? Does everybody put up such pictures? Do the people who put up the pictures sell their goods at the same price as the people who have no pictures? Do not the people who buy goods know their character and value?" You will wonder at what seemed so simple in this Swedish gentleman, but he was one of the foremost citizens of Gothenberg, an owner in a large works there, and a public officer of the government.

In the Scandinavian and other northern countries of Europe the sensational kind of advertising is or was at that time almost unknown, and such trade matter as was published had the same confidence as is accorded to secular literature of any kind It was

for information alone, and any attempt to secure trade by appeals to impulse or credulity would have failed of its object entirely.

These circumstances are mentioned to show that the sensational form for published trade is not universal, consequently is not essential, but the strangest fact of all is that people accounted as being skilled in trade and common sense are most given to sensational and factitious advertising.

Coming now to the practical part, all matter addressed to the public should be written in the third person. "I," "we" "us" and "ours" imply the "person," which has usually nothing to do with the goods advertised, besides there is a question of good form in in all kinds of writing addressed to the public or to an unknown reader. This address of the first and second person is a common but most undesirable custom, done in ignorance of good form in most cases, no doubt, but nevertheless undignified and is unnecessary. The custom of writing advertising matter in the first person is unusual in England among the better class of firms, especially those in engineering pursuits, and many of the leading firms in this country have decided that advertising matter should be written in the impersonal form, and have such a rule, but, as remarked, common custom is otherwise. Jones, Smith and Brown are mixed up with their goods in a way repulsive to good taste, and, as remarked, is not in good form.

With some practice it is just as easy to write advertising matter in the third person as in the first. One indicates education, and the other the want of it; also indicates a business conducted in an orderly organized manner, the other does not. These lectures delivered in person, and in your presence, admit of the personal pronoun, but if read before you by some one else they should be written in the third person. The same rule applies to advertising matter.

In these remaarks upon advertising matter it is not intended to disparage what is attractive or invites attention, but there are appeals to taste and appeals to credulity. Good paper, clear type, and, above all, orderly arrangement of matter, constitute attractive features to intelligent people. Fancy colors, decoration and exaggeration repel intelligent people.

As to methods, these vary in many ways, and each system, to so call it, has something to recommend it. Different kinds of business require various kinds of advertising matter. Commodities that are commonly understood, such as machine tools, for example, need a good illustration and brief specification, but a new manufacture

or machine requires a good deal more than this, because the reader in addition to dimensions and capacity must be instructed in the purpose and functions of a new machine or other product.

Many of the leading engineering firms employ no printed matter, indeed cannot, because the work produced is not uniform enough to permit of fixed illustration and description. Circulars, or what we call catalogues, pertain to manufactures or duplicate things. A maker of land engines devoted to some special kind of duty, what we call high-speed engines, for example, can issue a catalogue that will completely describe his engines. Their proportions, weight, horse power, prices, and so on, can be set down in tables and lists, and the information is complete. He is a manufacturer, in a modified sense of that term, but a maker of marine engines cannot issue such lists, because the engines made are not uniform as to design and adaptation.

In San Francisco the large works can with some success issue circulars of mining appliances, because these have become tolerably uniform, but very little beside can be advertised in this manner. We may assume as a rule that a catalogue or bound circular is suitable for a manufacture, but not for an engineering or other works that produces special things made from variable designs.

Most of the larger engineering works in this country, have at some time attempted to publish their work by set publications, and in most cases it has proved a failure, outside of some regular manufacture that the business included.

A plan that has met with some success, is to print single sheets, each devoted to some particular commodity or machine with a distinguishing number that will answer for catalogue or list purposes, and sometimes as a page number, so that a bound circular can be made up from such sheets to comprise a class of work, or if necessary several classes. This system has a good deal to recommend it, and has the warrant of endurance, having lasted many years in some of the best regulated works here and abroad.

The principal firms and companies in this and other countries, have since sun printing came into use relied wholly on photo prints, blue prints and tracings for illustrating their work, and on press advertising to secure acquaintance and connection. This we may call the most advanced method where there is the required skill and extent of business to permit it.

In advertising matter and tenders there are some conditions that are quite different here from European countries. Our market is

mainly at home and is homogeneous. One method will apply to all, but this is far from true in respect to England, France, Germany and Belgium, where a large share of the work made is sent into foreign countries where customs and requirements vary greatly.

I once overheard some remarks in the draughting room of the Stanley Works, in London, in respect to tenders, that will illustrate what is meant. It was the custom then, when sun printing had not been discovered, to make tracings on thin paper to accompany estimates and tenders. Such tracings were commonly colored in a rapid manner with a brush, and were, all things considered, the most effective of any method of illustration that has ever been adopted.

The managing partner at the works named went into the draughting room, where a number of boys were engaged in preparing tracings for tenders. Going to one of the desks he asked: "Where does this tracing go?" "To Madrid, sir," said the boy. "Color the brick work with vermilion, tint every piece and put on a fine border," said the owner. At the next desk a similar inquiry was answered: "Germany, sir." "Be careful about scale and dimensions, smooth lines, no tint," were the instructions.

Now whether the vermilion in the Spanish tracing was required by custom or for pure trade reasons we need not inquire, but that it was expedient there can be no doubt. The German estimate would have to withstand analysis on its engineering merits. That was well known, and while we did not see the specifications in these two cases, there is no doubt these corresponded to the chromatic work in one case and the technical dress in the other.

We need not deny the influence on the mind, or the "impression," which is a better term, produced by a neatly made tinted tracing. It may not be logical to admit, or a compliment to intelligence, but every one is more or less influenced by the manner in which a tender is made out in respect to its neatness and good appearance. I am speaking of illustration only, but specifications are subject to the same rule, and before treating of these separately I will introduce a story in illustration.

In 1883, or thereabout, the City of Sacramento having been flooded with storm water every year, decided to adopt some means of lifting the surface drainage and discharging it over an embankment into a slough leading to the Mokelumne River. The city engineer, Mr. Bassett, under instructions from the supervisors of the city, applied to various firms at the East who made centrifugal

pumps for tenders of machinery to raise and discharge the water against a head of ten feet or so, and among other such inquiries or invitations one was sent to a company in San Francisco with which I was at the time connected, the reason for this being that a pumping plant of the kind I had some time before erected near Stockton, in this State, had given very good results.

Drawings were carefully made of a vertical or submerged centrifugal pump and its connections, with an engine of seventy-five horse power, buildings, boilers, furnaces and all required accessories, down to a steam whistle and weather vane. Specifications were made out with dimensions, a guarantee of duty, efficiency, the amount of fuel, terms of erection, trial, acceptance and payment, and were sent in with the drawings.

On the day the tenders were examined by the Board of Supervisors, a telegram was received from them requesting the presence of some one from our company. I went up to Sacramento, and was called into the engineer's office, where the Board was in session and the various tenders were being examined, and was much astonished at such an invitation, but the reason soon appeared.

The engineer said: "We have here a collection of circulars, wood cuts and letters, non-committal, vague, and with no exact information or conditions of any kind, claiming a duty in many cases impossible, or inexpedient if possible; in short, your estimate and tender is the only one before the Board that should be considered." He then turned to the Mayor of the city and asked for instructions, after which the pile of letters, circulars and printed matter from other makers was laid on the waste basket and rammed down by the engineer's foot. The Mayor handed me our specification, and said: "Proceed at once, and we will send you a formal acceptance." This work was put in as specified, tested, accepted, and remained in use until 1893, when the lift or head was doubled, so as to discharge into the Sacramento River, and a new pump was put in. This is an example of what a complete tender will do in such a case.

Such a circumstance could not take place at this time, and would not then if there had been as there are now able firms on this Coast constructing draining machinery. At that time centrifugal pumps of the form required for the work at Sacramento were a kind of manufacture carried on in the Eastern States, and very poorly carried on, but now much improved there, and still further improved here.

As to specifications for tenders, it would be a hackneyed expression to say they should be carefully and explicitly written. Every one knows that, but there are some other points that may be mentioned here, among these abbreviations and omissions.

Dr. Johnson is credited with saying that "any man who would make a pun would pick a pocket." This is severe, and perhaps deserved, so is the corollary that any one who will omit the definite article in writing a specification should lose his labor.

How and why such a common custom of writing came into use it would be hard to find out, unless it be on the principle that inclination is always toward error. The indefinite article, a or an, which means simply one, and is almost a superfluity in our language, is more carefully treated and is not so often omitted, but the definite article, required for euphony if nothing more, is commonly dropped out of specifications to the great detriment of form, giving an impression of slovenliness, wholly inconsistent with good work and exact methods.

Charles Dickens, who was certainly a model in rhetoric, if not etymology and syntax, never employed figures in his writings, because these are abbreviations. He spelt out all dates and quantities without missing a letter, and thereby has given us a smooth example in the works of imagination and fancy, so have most great writers on all kinds of subjects. This is not, of course, necessary in specification, but will illustrate the inconsistency of abbreviation and contraction in technical matters and in language to describe facts and exact things, involving risk and often great sums of money.

TECHNICAL TERMINOLOGY.

I will now revert to technical terminology in specifications and advertising matter, and must first thing disclaim a pretense of treating the subject on a philological or even an etymological basis. Few practical men, perhaps none, have the time required for examining and tracing out the technical terms in use, besides many terms employed are arbitrary, and have no base for investigation, still it is proper and profitable for every one who has to speak or write of technical matters, and this is every one engaged in or managing industrial pursuits, to as far as possible employ names that are relevant, or have the warrant of use by educated people.

It is proposed to deal at some length with this subject. It is one deserving attention, because the constant efforts of our best writers and speakers are not enough to keep our technical terminology in anything like correct form, or what it should be for the purpose of

translation into other languages. There are, however, common-sense rules, where grammer cannot be applied, and every one can lend some aid by their own efforts if they set about it.

The development of industrial art during the present century has called for thousands of new terms to define objects, commodities and process not known before, and these terms have, in most cases, been adopted from accident, generally from the workshop, sometimes relevant, sometimes in jest, and frequently in slang.

There has been no attempt at methodical nomenclature, except in electrical terms, and you all know the conventions, discussions, and dissentions also, that have arisen in settling electrical terms, now happily at rest let us hope.

The art of naming things does not seem to have been much considered in this country. We have every facility for acquiring names from other languages not now spoken among us, and this is a very important and proper source for names, because of their having no separate meaning in our own language.

I have noticed that in England, and the northern European countries, they seem to manage without the appropriation of other useful terms for names. One may, for example, read over a list of post towns there, thousands of them, and in the whole not find a dozen names that have other significance. It is a rule, and a good one, that proper names of all kinds should apply only to the object, place or thing to which they pertain. A proper name should mean one thing, and not be borrowed from something else, so the meaning will be double and in doubt.

We have in this country the worst geographical nomenclature in the world, and our technical terms have to some extent suffered by the bad example. Almost every prominent city in Europe has its name repeated here, sometimes in a dozen places. Even the old names of Greece and Rome have been dragged into service, and our principal State, New York, has a Rome, Syracuse, Athens, most likely a Berlin, London, Paris, Hamburg and Vienna, so have many of the Middle States. This is provincial and useless. The Indian names, many of them fortunately adopted, furnished a source from which could have been taken names for our mountains, rivers and towns without appropriating names already in use.

On this Coast we are more fortunate, because of the Spanish names and terms, that to us have no significance beyond the thing or place to which they are applied. Palo Alto, for example, means to us, and all English-speaking people, a particular place, and no other place. In Spanish it may mean an elevated place where the palo or

alotun grew. It is a beautiful and relevant name, even in Spanish, and for use now by English-speaking people is perfect. Suppose it to be instead a borrowed name, from some other place, Upsala, Oxford or Cambridge, for example.

Reverting now to technical terms and their use in advertising matter and correspondence, also in records and in a works. I will name some examples of misuse, and first mention the name "stack," as applied to a chimney in this country. There is no need of calling a chimney a "stack." That is an old English word of Latin origin, meaning a pile, generally conical, of straw, timber or other material, but never a chimney. The name might with some relevancy be applied to a blast furnace as a structure, but not to a common chimney, especially to an iron pipe or flue.

"Track" is another word commonly applied to a railway. We say track for the ways or rails, but this is irrelevant and incorrect. The word, as every one knows, means a print left by something passing, especially the foot of a person or animal. It is from the German *trek*, to draw or illustrate by a print or impression. We say "railroad" instead of "railway." A road is something else, a way on which we drive wagons and travel, and railway or a way of rails is more relevant. We call a tooth wheel a "gear," and the term gearing for that reason has come to mean toothed wheels, but "gearing," as I need not say, does not mean tooth wheels, but may include a variety of things such as shafts, rods, wheels and the like.

Many machine tools are beginning to acquire names that if not slangy are incorrect. For example, a "drill," "planer" and "miller." Now a drill is an implement employed in a drilling machine, and what are we to call the implement if the name is applied to a machine? Planer should mean one who planes; a person, not a machine. The *er* is a contraction of the German personal pronoun *herr*. Planing machine is the correct term. Miller should mean one who grinds grain, or mills with a machine, not the machine itself.

By parity of reasoning, a lathe should be called a "turner," and it may some time at the present rate of progress in bad nomenclature. We call a screw key a "wrench," but there is no authority for making a substantive of this term. It is a verb, a longer word than "key," and is not relevant. We might as well call a velocipede a "ride."

The term "lumber" is another one that has been torn from its moorings, so to speak, and applied to sawn timber. It is an old

English word, meaning cumbrous or waste material, and has in common replaced the old Saxon term "timber" or *zimmer*, which contains the same number of letters and is the true name. "Builder," applied to a maker of machines or other commodities that are not built up by an accretion of parts, is another term that is bad. Maker is as easy and sounds as well. One can build a house or a ship, but not build a machine or a hand saw, besides the term "builder" means specifically one who builds houses. The distinction is plain.

These few names have been selected because they are not employed in the same sense in other countries where the English language is spoken. My attention was very forcibly drawn to this fact of a varied use of terms, as will appear a little further on. This want of uniformity is unfortunate, especially in respect to technical terms that arise in foreign correspondence and in advertising matter to be translated, or is addressed to people not acquainted with the idiomatic or local use of such terms.

Lexicographers who in dealing with words set down their idiomatic use in certain localities or countries, are the principal cause of such confusion. Suppose, for example, our American lexicons set down the term lumber as meaning waste or obstructive material, and nothing more. People would at once fall into a correct use of the name. On the contrary, however, the lexicons, technical and other, seem to be based on description instead of authority.

This matter of an improper use of technical terms has a result in advertising matter not always thought of. It is easy to see that whatever the merits of our standards or lexicons may be, any one in a foreign country seeking for such authority in technical terms of the English language will naturally consult an English dictionary, and any of the words before named thus translated into any other language would give a queer result. I am well aware of the great and successful work done by Americans in framing lexicons for the English language, and also of their fault in not more clearly pointing out and condemning the misuse of technical terms that should be uniform wherever the language is spoken.

To illustrate the importance of a correct use of technical terms I will relate a circumstance that will explain my personal interest in the subject. In 1873 I prepared a small book called the *Operators' Hand Book*. It related to wood-working machines and processes, and was supplementary to a much larger and different book on the same subject. It was published in London, and I may mention that an edition of 2,500 copies were sold in a few years, so it had some value. When the book was nearly all in type, the publisher

called at my office with some of the proof sheets, and asked: "What do you mean by this term 'lumber,' do you mean 'timber?'" "Yes, sawn timber," I replied. "But," said he, "how are readers to know this? I never heard of such a name applied to 'useful' timber."

I went to the dictionary, and to my consternation could find no authority for such use of "lumber." This book was mainly for use in Europe, and there was nothing to do but to lose and reproduce most of the forms then printed, and eliminate lumber throughout. This cost thirty pounds sterling, or $150, and was a very expensive lesson in etymology.

This subject has a very practical application. This country by reason of its great natural resources, wealth, skill, geographical position, also by the trend of present facts, is destined to become a great exporter of industrial products to the neutral markets of the world. Our natural markets lie to the south in America, and to the west in Asia, where people have a disimilar civilization and pursuits. Our trade to Europe in skilled products is an accident, or at least is without permanence, except in food or other natural products, but trade the other way will be natural and enduring when the genius and policy of the country is brought to bear on such trade. These markets will be strongly contested, and young men here now will be middle-aged before this trade is fully established, but it must be prepared for now. It has indeed begun, and will increase only as we learn the wants and customs of the people to be dealt with, and proper means of selling.

Our trade terms, advertising matter and correspondence to promote such trade must be uniform and as exact as possible. We cannot successfully incorporate obscure and incorrect names in such matter, terms that will not translate into a proper meaning. If we do, it will be construed as a lack of care and education, both of which commands especial respect among Oriental people, and, we may add, in some of the States of South and Central America, Chili and the Argentine States, for example.

We cannot or should not send an invoice of printed cloth and call it "calico," because that is not the name of such cloth there. Calico from Calicut, in India, where such cloth was first made from cotton, does not mean prints. Drugs do not mean chemicals or medicines in the terms of trade now in use, and so on through a long list of trade names.

These markets are now to a great extent supplied from Great Britain, and the terms and names are learned from British merchants. We cannot change these terms and need not, because they are as a rule relevant and correct, at least, are equally so with those we employ here.

Some years ago Mr. Otto Schleischer, of Schleischer, Schumm & Co., owners of the Otto Gas Engine Works in Philadelphia, visited me at San Francisco on his way to Germany. I remarked that he seemed to be going the wrong way to reach Germany, and his answer was: "I am a member of a kind of linguistic society in Germany, and we are just now compiling a lexicon of certain native languages in Africa. There are some points unsettled, and I am going by the way of Zanzibar to gather the required information there." I expressed surprise at an African dictionary. "Oh," said he, "this is the third one. Our people are preparing for trade in Africa, and the first requirement is to know the native languages, so as to translate correctly."

The phenomenal work done by the German people during twenty-five years past in not only founding successfully nearly all branches of skilled industry, but in founding trade connections while their material was enhanced in value by customs taxes, is one of the wonders of this period. Professors Smith and Marx, who are well acquainted with this matter, will, no doubt, bear me out in saying that the administration of German works has furnished a lesson to the world, and against various impediments there have been founded industries and a trade of great extent in a period half as long as in any precedent that history furnishes.

This has been done by various agencies, many of which you are acquainted with. Among these has been a careful attention to terminology, and as Germany is the home and head of philology, a translation of their technical terms will establish the truth of what I have endeavored to explain in the latter part of this lecture.

It remains only to thank you for the kind attention given to these lectures, prepared under various adverse circumstances, also to thank the Faculty who have courteously permitted me to frame the matter in terms and in order, that are more shop-like than academic. My chief interest is to know you have accepted my efforts as a sincere attempt to say something that will be remembered, and prove useful in your future experience.

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